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RECENT CHANGES OF CLIMATE AND VEGETATION IN SOUTHERN NEW ENGLAND AND ADJACENT NEW YORK

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INTRODUCTION

BOTANICAL STUDIES in the Hudson Highlands of southern New York State have suggested the present inquiry into changes which may have occurred in the vegetation during very recent geologic time. By "recent" is meant the past 3000 years or less. The configuration of timber types on the granitic hills in the Black Rock Forest fairly typifies the Highlands region, and is essentially as follows.¹

Most of the slopes, which for the most part are steep and rocky, are clothed with a forest of red and chestnut oaks (*Quercus borealis* and *Q. montana*, respectively), associated with other trees in less abundance. Formerly the chestnut (*Castanea dentata*) was one of the primary species. In general, the red oaks are more abundant on the lower slopes, and the chestnut oaks on the upper; but in very rocky places the chestnut oak is likely to predominate even at low levels, while the red oak may predominate at high levels if the slopes are gradual. The intervals, or coves, have a mixed forest in which sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), linden (*Tilia glabra*), yellow birch (*Betula lutea*), tulip-tree (*Liriodendron Tulipifera*), red oak, and red maple (*Acer rubrum*) are the commonest species. Beech (*Fagus grandifolia*), American elm (*Ulmus americana*), black birch (*Betula lenta*), white oak (*Q. alba*), shagbark hickory (*Carya ovata*), and a few other species of similar requirements are usually present in smaller

¹General collections and field notes were made in the Black Rock Forest in the summer of 1936. This material is to be embodied in a forthcoming, more or less detailed description of the flora and types of vegetation. For a more complete description of the Forest than appears here see Tryon, '30.

numbers. Northward-facing ravines and lower north slopes usually have a larger percentage of hemlock (*Tsuga canadensis*), and in a few restricted localities the beech becomes a primary tree. Within the Forest area most of the cove timber lies between 450 and 1100 feet above sea level.

The crowns of the hills, most of which lie between 1200 and 1450 feet above the sea, are distinguished by two types of vegetation. The southwest sides usually have an open scrub of pitch pine (*Pinus rigida*) and scrub oak (*Q. ilicifolia*) interspersed with grassy areas in which *Andropogon scoparius* var. *frequens*, *Danthonia spicata*, and *Deschampsia flexuosa* are the commonest species, together with some small shrubs such as *Vaccinium pennsylvanicum*, *V. vacillans*, and *Prunus pumila* var. *susquehanae*. The northeast sides are usually covered with a rather scrubby forest of white oak and pignut hickory (*Carya glabra*). Associated with these trees is usually a dense growth of *Viburnum pubescens* var. *Deamii* which constitutes most of the shrub cover. This association is extremely limited in extent, rarely descending below the crown of the hills, and then only on warm southern slopes. The *Viburnum* is rarely met with anywhere in the region except in these restricted areas.

There is considerable evidence that this arrangement of forest types is essentially the same as that which occurred in pre-colonial times, in spite of the long period of exploitation. This evidence, which will not be discussed in detail here, is mainly in the growth-form and position of very old trees, in the general condition of the soils, and in old records.¹

It will be readily seen that we have here representatives of three forest types whose geographic ranges are different and fairly distinct. The cove forest is clearly a modified form of the hemlock-northern hardwood type which is commonly associated with white pine and ranges throughout much of the northern Great Lakes states and New England, sending a long tongue southward along the Appalachians (Nichols, '35). The coniferous element is poorly developed in the Highlands region; and the northern hardwoods, instead of being dominated largely by beech, sugar maple and yellow birch as they are farther northward, show a mixed facies as noted above. The chestnut oak - red oak-(formerly) chestnut association of the slopes is closely related to the forests of similar situations in the southern and middle Appalachians (Weaver & Clements, '29; Shreve, Chrysler, Blodgett & Besley, '10). The white oak-hickory association on the other hand is typically middle-western, having its best development in the Mississippi basin. This western

¹Further discussion of this matter will be found in the writer's projected botanical report on the Black Rock Forest.

affinity is accentuated by the local abundance of *Viburnum pubescens* var. *Deamii* which is here near its eastern limit, and is a common form of the species in the middle-west.

From the standpoint of silvicultural planning it becomes of interest to know the significance of the three types. Is the present state of affairs a static one; or may it be expected to change during the succeeding generations of commercially grown trees? If the latter, may the white oak-hickory type be expected to expand over more of the slopes, with a corresponding restriction of the cove type, suggesting a warmer and drier condition; or may the commercially valuable cove timber be expected to expand up the slopes and the oak-hickory type be still further reduced than it is at present, suggesting a somewhat cooler and more moist situation? In case of the former, the chestnut oak could be expected to occupy more of the slopes than it does at present, and in case of the latter it would probably be more restricted than at present.

There is no reason to believe that the present distribution is a static one, particularly in view of the vast amount of evidence to the contrary in most of the temperate and subarctic regions of the world. To name only a few sources: the succession of vegetation shown in recent peat deposits; fossil floras of other nature involving longer periods of time; the advance of forest into prairie in middle-western United States within historic times, and the oscillation of prairie-forest boundaries in comparatively recent post-Glacial time in the same region. The major problem seems to be rather to determine which way the change is going, and its probable rate.

The present geographic ranges of the three forest types mentioned above are commonly, and probably rightly, thought to be determined by climatic and historical factors operating over very long periods of time. The climatic influences of the Appalachian Mountains on the one hand, and the increasing aridity toward the westward in the Mississippi basin on the other, acting through long periods in the evolutionary history of the deciduous forests, have led to the development of the xerophytic chestnut oak-chestnut, and white oak-hickory types respectively (Weaver & Clements, '29).¹

¹There is the suggestion here that we are dealing with a group of forest associations which may be as old as the species which compose them. There is some evidence that the most ancient of the group was the more mesophytic type, consisting of beeches, with ancestral oaks and chestnuts. The scanty fossil evidence indicates that these date far back in the Cretaceous, whereas the modern lobe-leaved oaks, for instance, as well as the hickories, are not known as fossils until the early Tertiary (Berry, '23). If this is the case it is not unreasonable to consider that these xeric expressions within the deciduous forest appeared under the stimulus of the aridity which developed in the interior of America early in the Tertiary.

The persistence of such forest complexes for very long periods of geologic time has

THE PRE-COLONIAL FORESTS

Oak forests in which white, red, and black oaks are predominating elements are characteristic of southern New York and most of southern New England east of the Berkshires (Mass., R. I., Conn.) (Nichols, '13; Bray, '30; Hawley & Hawes, '12). The hickories and the tulip-tree are commonly associated with the oaks, and chestnut was formerly a primary part of the association. The whole has long been classed by foresters as "sprout hardwood"¹ on account of the abundance of reproduction by this method. Except for parts of extreme southeastern New England (S. E. Conn., R. I., and Cape Cod), these oak forests are generally regarded as of secondary origin, i.e., they have come as a result of fire or clearing (Nichols, '13 and '26; Bray, '30; Hawley & Hawes, '12; Lutz, '28; Weaver & Clements, '29; Bromley, '35). The forest type which is generally considered the "climax" in this region, that most nearly in accord with the climate, is a mixed timber of hemlock and the northern hardwoods such as beech, sugar maple, and yellow birch. The white pine (*Pinus Strobus*) is usually regarded as a characteristic tree though its abundance in the primeval forest is thought to have been local at least in New England (Fisher, '33; Nichols, '13 and '35). Arguments for the recognition of this type as climax are adequately summarized by Nichols ('35); and in spite of the fact that the forest bears many characteristics of a transition from the Canadian coniferous timber of spruce and fir to the deciduous woodlands farther south, there seem to be sufficient distinctive characters to warrant its separation.

If the oak forests are to be regarded as temporary in much of southern New England, and likewise the white oak-hickory type in the Black Rock Forest, then it appears necessary to regard the secondary influences as

been pointed out by Chaney ('25), who has based his studies upon the redwood forests of California.

The silvicultural significance of this concept is readily seen. When type-mapping, cruising, or otherwise describing woodlands the forester commonly uses *groups* of species as units; but when working out his silvicultural methods and programs he is prone to deal in *single* species, encouraging or retarding them without much regard for their associational relationships. The final result of such a breaking up of natural associations cannot be predicted without much more knowledge of the species and their relationships than is now available, but the excellent results obtained when the natural associations are in large part preserved are becoming evident in those experimental stands where this is being tried (See Tarbox & Reed, '24; Cline & Lockard, '25). These results, coupled with the probable antiquity and relative permanence of our common forest associations, suggest that further knowledge of the bonds with which the latter are held together would be of great silvicultural value.

¹This term will be used throughout the paper to designate an association dominated by oaks (mainly white and black), hickory, and chestnut, with the tulip-tree a common constituent. For a general discussion of eastern forest classification see Toumey, '28.

having begun before the advent of Europeans. It has already been noted that in the Hudson Highlands the present distribution of types probably antedates the colonial period. Recent studies in southern New England point to the same conclusion, as expressed in a recent paper by Bromley ('35). Unfortunately the early writers cited by Bromley do not, with one possible exception, present adequate evidence on the interior uplands of the region for which information is most needed. He relies most heavily upon John Smith (1616), Thomas Morton (1632), William Wood (1634), John Josselyn (1672 and '75), and Timothy Dwight (1821). Descriptions written by the first four of these all indicate clearly that the coastal strip was forested primarily with oak and pine, but there is no indication that any of them visited the interior or obtained reliable information on it. Dwight's travels were in the early 1800's or very late 1700's, and were not published upon until 1821. It must be remembered that at this time some of the inland settlements in the Connecticut valley were over 150 years old; and even the youngest of the upland agricultural communities of central New England were at least 50 years old, and many of them twice that age. It must be noted also that the clearing of land for cultivation and pasture was approaching its maximum in many communities (Fisher, '33). It is probable, however, that Dwight was describing remnants of the original forest in some districts, particularly in the younger towns of central Massachusetts.

With these things in view it is pertinent to examine contemporary histories written during the 1700's. A number are available, but most of those found thus far by the present writer have yielded nothing of interest in this connection. The one notable exception is Peter Whitney's *The History of the County of Worcester*, published in 1793. Whitney was a clergyman who was born in 1744 in the western part of this county, in the town of Petersham. He was educated at Harvard College and held a charge at Northborough, Massachusetts, from 1767 to the time of his death in 1816.¹ His history must have been written, therefore, while many of the towns in the county were less than 50 years old; and his observations must have extended back somewhat further than 1767. There must have been relatively large areas of primeval

¹The writer is indebted to Mrs. Mabel Coolidge of Petersham for references bearing upon the life of Peter Whitney. These are to be found in "An Address Delivered in Petersham, Massachusetts, July 4, 1854, in Commemoration of the One Hundredth Anniversary of the Incorporation of That Town," by Edmund B. Willson (Boston, 1855). That Whitney had an early interest in horticultural matters is shown by his note communicated to the American Academy of Arts and Sciences (See *Memoirs of this organization*, Vol. 1, p. 386) on the subject of a curious hybrid apple tree in his native town.

forest in the region during his lifetime. The history was written by towns, and in each description is a brief account of the existing timber, with notes on its earlier condition if such were available. Whitney's knowledge of the common forest trees was evidently quite extensive, for in no other way can we account for the detail with which his notes are given. Two checks upon his accuracy are available. One is the manner in which his records of scattered pitch pine plains agree with the known distribution of these. The other is the way in which the hemlock-northern hardwood forest of Winchendon and parts of adjoining towns stands out clearly, just as it does today, in a county otherwise described by him as dominated largely by oaks, chestnut, and "walnut."¹ His descriptions leave little doubt that in central Massachusetts at least the pre-colonial forest was primarily of "sprout hardwood" species. Although the hemlock-northern hardwood forest was predominant on the uplands in parts of the most northern towns, it seems to have been limited elsewhere to lower slopes and ravines.

The aborigines of southern New England were a semi-agricultural people, but there is no evidence that their clearings of the forest ever went beyond relatively small localized areas. Consequently, if a secondary agency is to account for the presence of the oak forests, fire is the only one conceivable. Bromley has cited the comments of several early writers on southern New England in support of the hypothesis that most of the forests of this region which were dry enough to burn (oak-chestnut-hickory and pine) were burned at least once a year by the Indians for centuries before the coming of the white man. It is his opinion that these forests were maintained in this condition by such recurring fires, although he suggests that some of the oak-chestnut-hickory forests in his present "white pine region" may have been edaphic on the drier sites (Bromley, '35, p. 74).

There is no question but that fire has always been a factor in the control of forests, whether set by lightning or by man; and there is abundant evidence that the Indians deliberately set fire to the woods on occasion. Furthermore, anyone who has observed the modern descendants of the red man living in the wild will attest to their common carelessness in putting out campfires. But to picture such a wholesale conflagration in Massachusetts, Rhode Island, Connecticut, and southern New York State as would involve most of the inflammable woods every year, or even every 10 or 20 years, is inconceivable. Even if the forest were not entirely destroyed as a whole, at least the undergrowth and herbaceous species, to say nothing of the animal life, would have been

¹In the early writings "walnut" was a general term for both *Juglans* and *Carya*.

nearly or quite destroyed over large areas. Yet the country was known to be teeming with game even near the coast when the colonists arrived, and there has never been any evidence of the early elimination of large populations of woodland plants in these regions.

Two sets of facts are worthy of note in this connection. First, the significance of the early writings is open to question here as it is in descriptions of the timber itself: the coastal strip is the only area for which authentic information is available.¹ It is of interest that Peter Whitney makes very few references to fire of any kind in his history of Worcester County.

The reasons assumed by the early colonists for the firing of the forests are also of interest. They appear to have been impressed first, not by the fires, but by the openness and park-like character of the woods. They attributed it at once to the efforts of the natives, usually giving as purposes either the improvement of visibility and travel by eliminating the undergrowth, or the "improvement" of pasturage for game by encouraging the growth of grasses and other herbage in the forest.² Without exception these writers were western Europeans whose ancestors had lived for centuries in a region continually under the influence of civilized man; consequently it was difficult or impossible for them to conceive of open, park-like woods growing naturally, without human intervention. Natural woods was for them of necessity a dense growth, either of conifers or of coppiced hardwoods such as they knew in Europe or the British Isles.

Open, park-like woods have been, from time immemorial, characteristic of vast areas in North America. Almost anywhere one chooses to look on the periphery of the great arid plains of the interior of the continent he sees this savannah or park-land extensively developed. Its occurrence far eastward in Ohio has led to some of the most interesting and far-reaching hypotheses in American plant geography (Gleason, '23; Sears, '33 and '35a; Transeau, '35). Most of the initial reactions of Europeans to these western park-lands or open woods have been identical with those expressed by the earliest New England colonists: that they had been caused by fire, usually thought to have been set by

¹For comment on the dearth of information about the interior of New England in 1630 see the edition of Thomas Morton's *The New English Canaan* published by the Prince Society, Boston, in 1883, with introductory matter and notes by the historian Charles Francis Adams. Morton was notably inaccurate in many lines, and was doubly so when writing of the interior. He wrote with seeming authority, but in fact quite at random, about the country around Lake Champlain, and farther south he confused the Hudson and Potomac Rivers.

²In addition to the early New England writers cited above see also Van der Donck (1656).

the Indians. This manner of explanation persists to the present, and recently discovered park-lands in northern Canada have been accounted for by some travellers and students in the same way.¹ No one will doubt that fire has had a significant influence in determining the presence of park-land, but wherever detailed and careful studies have been possible, fire has been slowly forced into the background as an actual *causative* factor, and fundamental climatic, edaphic, and historical factors take their rightful precedence (Sears, '33 and '35a, b; Moss, '32; Transeau, '35, p. 434).²

It seems necessary therefore to question rigorously or to discard in large measure the evidence of early writers for the relative openness of the woods on the inland region of New England and southern New York. Likewise it is doubtful whether the reasons they have given for the openness near the coast can be accepted at face value. Judging by what is known of park-lands and open woods in general, and particularly in view of the similarity between the southern New England oak-hickory forests and those of the middle west, it is more logical to think that the pre-colonial oak-chestnut-hickory type which prevailed in much of the region was the normal vegetational expression of the climatic-edaphic complex which had obtained here. No doubt fires helped to maintain it against the competition of the more mesophytic forests to the north and northwest, but that fires were the sole factor in maintaining it is difficult to believe.

With the antiquity of the oak-chestnut-hickory forests in this region fairly well established, the question naturally arises as to why they are almost universally regarded among foresters as temporary types except in the extreme southeastern sections. Two reasons might be suggested. One is the widespread concept that clearing and fire have caused radical changes in the composition of the forest, and that since practically all of the original forest in this region has been destroyed the present stands are very likely to be different from the original. By further reasoning along this line it is assumed that if the present stands are properly protected they should revert to this hypothetical original state. There is abundant evidence in support of this concept, particularly in southern New England where such a large percentage of the land was allowed to

¹For discussion and citations in this connection see Raup, '34.

²Gleason postulated two advances of prairie vegetation into the middle west. The first he thought was due to an extension of arid climates, but the second he accounted for by the appearance of the Indians who drove the forest back with prairie fires. The forest advance of modern times he attributed to the protection from fire which was afforded by white settlement. It seems more probable, in the light of Sears' correlations of evidence from many regions, that the recent advance (providing there were two of them) was due also primarily to a more arid climate.

return to forest after being cleared or under cultivation for several generations. The well-defined succession of facies in abandoned fields throughout this region is enough to account for the whole idea.

Another reason which might be advanced is that there is an actual progressive elimination of the oak-hickory forests from the region, and a corresponding advance of the hemlock-northern hardwood type. A great deal of evidence has accumulated which supports this. Old field timber at the Harvard Forest in Petersham, Massachusetts, tends to develop toward a forest of northern and "transition" hardwoods rather than toward one of white and black oaks and hickory¹ (Fisher, '18 and '28; Griffith, Hartwell & Shaw, '30; Spaeth, '20; Averill, Averill & Stevens, '23; Cline & Lockard, '25). The wide extent of this tendency in the northern half of Worcester County, adjacent Franklin and Hampshire Counties, and adjacent New Hampshire is shown in a recent survey of old field pine lands by McKinnon, Hyde & Cline ('35). Of 225 stands examined, involving approximately 2023 acres, only 15 stands covering 132 acres could be classified as of white oak-hickory type, and these were all in the southern part of the district. All of the remainder were noted as of northern or "transition" hardwoods, mainly the latter in which red oak, white ash, white and black birch, red and sugar maple are the predominant trees. Over a large proportion of this very region Peter Whitney described oak-chestnut-"walnut" forests early in the history of the settlements. Towns with such woods were Petersham (part), Athol (part), Oakham, Paxton, Barre (part), Sterling, Lunenburg, Harvard, Holden, Leominster, Westminster, Hardwick and Rutland. It is of interest that in a few places he recorded that the "walnut" seemed to be increasing. This was probably due to the opening of the oak-chestnut forests and may be observed throughout the oak-hickory regions of the middle west where clearing of old growth commonly gives rise to dense stands of sprout hickory very soon afterwards.²

¹It is presumed that the oak-chestnut-hickory forest described by Whitney involved white and black oaks more prominently than red. This is based upon the present known relationships of these species. The red oak is a primary constituent of the so-called transition hardwoods, in which the hickories do not play an important part; the latter are usually most abundant in association with white and black oaks in this region.

²An outstanding feature of the New England forests during the past 75-100 years has been the growth of white pine on abandoned farm lands. Vast acreages seeded in to nearly pure stands of pine very soon after they were abandoned, and produced a wealth of lumber during the latter part of the last century and the first of the present one. In fact most of eastern Massachusetts, northeastern Connecticut, and northern Rhode Island has come to be known as part of the "white pine region" (See Sargent, 1884; Hawley & Hawes, '12; Bromley, '35). It is thought, however, that in the hypothetical virgin forest of hemlock and northern hardwoods the white pine was "a normal, although minor, constituent," and that its presence in the climatic climax association was due to local, more or less accidental openings in the

The tendency for the hemlock and more northern hardwoods to succeed the oaks and hickories has been noted repeatedly in Connecticut. Nichols has this statement in a recent paper: "Not without significance also may be the fact that in Connecticut and elsewhere along the southern borders of this region [hemlock-white pine-northern hardwood] the hemlock and northern hardwoods gain successional ascendancy over oaks and other relatively southern trees when competing with them on the better soils . . ." (Nichols, '35). Lutz ('28) concluded, on the basis of a careful study of forest successions in southern New England, that the major trend was toward a hemlock-hardwood type, and Bromley ('35) appears to be of the same opinion.

There is good evidence therefore that within the past 200-300 years some of the more southern elements in the forests of central New England, notably the hickories and walnuts, have been partially eliminated, and that the secondary forest successions in southern New England east of the Berkshires generally are trending toward a forest of hemlock and northern or transition hardwoods rather than toward one involving white and black oaks and other "sprout hardwoods." If the pre-colonial forests were primarily of oak-chestnut-hickory over most of this region, then we are confronted with the question of how this distinctly southern and western phase of the deciduous forest came to predominate in a region which now appears to be largely unsuited to it.

Although generally adhering to the idea that the sprout hardwoods in Connecticut were due to the influence of man, Nichols expressed some doubt in his early papers on the vegetation of that state as follows: "But the forest is by no means uniform in structure throughout the state. Most widely disseminated and of greatest economic importance is the "sprout hardwood" type which represents the usual climax formation over fully five-sixths of the state. . . . To what extent these modifications in forest composition should be attributed to contemporaneous factors cannot be definitely decided. In a measure the presence or

hemlock-hardwood stand (Nichols, '35; Fisher, '33). A question naturally arises as to the source of the large quantities of white pine which appear to have been available to the early settlers. With the pine so much in demand, it was the first of our forest trees to be seriously depleted in many regions. There is, therefore, a further question as to the source of the seed which produced the immense development of old field pine during the last century.

If the pre-colonial forest was mainly of oak, chestnut, and hickory, it might be expected that the white pine was far more abundant when the settlers came than is now supposed. This forest would have been relatively open and considerably drier than the hemlock-northern hardwood type, and more subject to fire. Under these conditions a considerable amount of second-growth pine could have developed during the period prior to wholesale abandonment of farms, this later to maintain a supply of lumber and to seed in the open fields. It is notable that Whitney records an abundance of white pine during the early history of many towns in Worcester County.

absence of particular species may be the result of geographic position, but it seems more likely that this scarcity or abundance is determined by physiographic or climatic factors" (Nichols, '13, p. 100). Bromley, on the theory that fire was the cause for the prevalence of the oak-chestnut forests, found it necessary to postulate extremely frequent conflagrations, extending over most of southern New England, and during centuries of time. The early colonial writers mention only the burning of oak-chestnut forests, since these were the only ones which were common near the coast; and Timothy Dwight (Letter VIII) states that the oak-chestnut and pine lands were the only ones regularly burned because only they were dry enough. If this was the case, then we must either assume that the "dry" forest of oak and chestnut was here before the Indian arrived, or that an ancient forest of hemlock and northern hardwoods very gradually succumbed to very frequent fires started on a few dry sites and encouraged by occasional dry years.

As suggested above, the absence of good evidence that such intense burning occurred on the interior uplands, or that it was significant on the coastal strip, must now be coupled with doubt as to the actual function of fire in originally *causing* the prevalence of sprout hardwoods. It seems necessary to look at climatic or edaphic influences of long standing in the region as a whole for further light on the matter, and to study the history of the vegetation with this broader aspect. Nichols suggested this in 1913, as indicated above; and Bromley has noted that climate might have been effective: "As we do not as yet have pollen analyses of peat bogs from New England, we do not know exactly how or when one forest type succeeded another. It is known, however, that in the middle west, a dry period occurred about 3000 years ago which resulted in a dominance of xeric species, principally oaks. Although there is no present evidence of such a period in southern New England, it is not unreasonable to suppose that such did occur and very probably was the basic reason for the establishment of oak and pitch pine forests which were maintained by the Indians' fires until the white occupancy" ('35, p. 68).

If a warmer and drier climate existed in southern New England within the past 3000 years it is reasonable to expect that there should be some evidence of it remaining. With this in view, and remembering that a warm-dry period in the southern Great Lakes states was first recognized entirely upon floristic grounds, without benefit of pollen analysis, the present writer has attempted to gather such evidence as could be found. Various lines of inquiry have yielded results: botanical, zoological, paleontological, and archaeological, and these will be presented in the following discussion.

ZOOLOGICAL EVIDENCE

The occurrence of a "Virginian" element in the New England-Acadian coastal fauna was pointed out as long ago as 1862 in a paper by John Willis which incorporated the observations and suggestions of Sir William Dawson. In later years the data have been greatly amplified, and various hypotheses advanced to account for them. An excellent summary of the problem to the time of its publication is in a paper by W. F. Ganong in 1890. He listed 28 species of molluscs and echinoderms, besides a group of marine algae, which are of southern affinity but scattered northward along the coasts of New England and the Maritime Provinces. The form most commonly cited as an example of this dispersal is the oyster, which now occurs only in a few places in these waters, but which was evidently much more abundant in colonial times. There are repeated references to oyster banks, for instance, in the Charles River basin at Boston (Hubbard, 1680; Josselyn, 1638 and 1663; Wood, 1634; Higginson, 1629), although these have long been extinct. Their abundance at various places along the coast in former historic times is proved by other early writings and by Indian shell heaps composed almost entirely of oyster shells. One of the largest of these heaps is in the estuary of the Damariscotta River in Maine. It has been studied recently by R. P. Goldthwait who also summarizes the present distribution of oysters on the Maine coast: "In Maine oysters are restricted to rocky current swept estuaries. Although numerous oyster beds thrive in the protected Gulf of St. Lawrence, further north, the relic colonies at Oyster River almost in Maine (Durham, New Hampshire) and at Sheepscott Falls, adjacent to the Damariscotta River, live in swift water nearly ten miles from the open ocean. These are the only known beds in hundreds of potential locations, and even they threaten to expire" ('35, p. 5).

There is abundant fossil evidence that oysters as well as many other southern forms were more common and widespread in northern waters in recent geologic time. Ganong reported the common occurrence of fossil oysters brought up from beds off-shore on the coasts of the Maritime Provinces (1890, p. 175). Upham summarized data from the vicinity of Boston in 1892 as follows: "Taken as a whole, the twenty-five species comprised in the identified fauna . . . belong in their present geographic range to a somewhat more southern and warmer portion of our coast. Fourteen are distinctly southern, and reach their northern limits at Cape Cod or in Massachusetts Bay, and in one instance near Portland, Maine; excepting that several of them occur in isolated colonies far north of their general and continuous range, as in Casco and

Quahog Bays, Maine, and especially in the shallow southern part of Acadian Bay of the Gulf of St. Lawrence, from Cape Breton Island to the Bay of Chaleurs. The occurrence of these southern molluscs, which are mostly now absent, or local and rare, north of Cape Cod, shows that the sea during some part of the Recent epoch has been warmer than at the present time" (1892, p. 203). Regarding the extinction of southern forms he states: "During the time of the accumulation of the aboriginal shell-heaps . . . of Maine, and even within the 270 years since the first white settlement in Massachusetts, very significant restriction and extinction can be shown. For example, Professor Verrill, 1874, states that dredging reveals the occurrence of great beds of oyster shells a few feet beneath the harbor mud at Portland, where they are associated with the quahog (*Venus mercenaria*), scallop (*Pecten irradians*), and other southern species; and that the oysters and scallops "had apparently become extinct in the vicinity of Portland Harbor before the period of the Indian shell-heaps, for neither of these species occurs in the heaps on the adjacent islands, while the quahogs lingered on until that time, but have subsequently died out everywhere in this region, except at Quahog Bay" (1892, pp. 208-9). Upham concludes that: "The extinction of oysters, and of their southern associates has been rapidly going on from Nova Scotia to Cape Cod since the earliest settlement of the country, due probably not so much to their exhaustion by being gathered for food, or to any and all other causes, as to the progressive refrigeration of the sea; . . ." (1892, p. 209).

More recent findings corroborate the above. Shimer, reporting in 1918 on the subway excavations in the Boston Back Bay district, describes the recent submergence of the coast, and the deposit of shell muds: "The shells inclosed in the mud deposited upon the peat since its submergence beneath the sea give evidence of two climatic periods,—an earlier period (4a) warmer than the present and a later colder period (4b) extending to the present . . . 4a This fauna, representatives of which are rare or altogether wanting off our coast today, is now dominant off the coast of Virginia, though it ranges from Cape Cod to Cape Hatteras. Of the sixty some species noted . . . about half no longer occur north of Cape Cod, or only rarely in sheltered places, but find their perfect environment farther south" (Shimer, '18, p. 456; Antevs, '28a, p. 93).

J. Brooks Knight ('33) has recently summarized the facts regarding the distribution of the southern gastropod, *Littorina irrorata*. This species was formerly abundant in a few sheltered places in Long Island Sound, but apparently became extinct there about the middle 1800's.

Its shells have been found abundantly, however, in a fossil fauna underlying a salt marsh near New Haven, and have also been found in Indian shell heaps in that vicinity.

The preceding notes on the coastal faunas of this region point clearly to a comparatively recent period when the waters were warmer, permitting an extensive northern dispersal of species now more or less confined to the coasts south of Cape Cod. The effects of the refrigeration of these warmer waters appear to have continued into historic times, as shown by the progressive elimination of species to the present. Furthermore, during at least a part of this time there was a subsidence of the coast. There can be no question that the final causes for the elimination of the oyster from our shores can be laid to invading Europeans, but this will not apply to the many species of no particular food value which have also been progressively restricted or eliminated, even within historic times.¹

The pre-colonial distribution of land animals in New England is greatly obscured by the changes which have occurred with settlement. A suggestive finding along this line is in a paper on the former distribution of the wild turkey, by Professor Glover M. Allen ('21). This southern bird extended northward along the coast at least to the Kennebec and probably to Penobscot Bay. Inland it did not range north of southern New Hampshire and Vermont, getting as far north in the former as Concord. Its northern limit is thus roughly coincident with the northern boundaries of the former oak-hickory-chestnut forests noted above. In fact, Professor Allen has suggested a definite relationship: "The limit of its range thus corresponds roughly to the transition faunal area, and was possibly more or less coextensive with the area over which red and white oaks were sufficiently abundant to furnish food in reasonable quantity. Possibly the apparent absence of the Turkey from most of Vermont is explicable through the comparative scarcity of oaks, whose place in the more limy soils seems to be in part taken by sugar maple, beech and butternut."

Many other southern birds can be cited as examples of the same range which have not been destroyed by the coming of the white man. Professor Allen ('02) notes the following in his study of the birds of New

¹Some recent investigations indicate cyclic fluctuations in the temperature of the inshore water on the New England coast. These studies have been made in connection with the recent increase of the shipworm, *Teredo navalis*, a boring mollusc which does great damage to marine pilings. Several other southern organisms are enumerated which also appear to be increasing in New England, but whether or not their coming may be related to minor climatic changes is not determined. The water temperatures show a rise since 1925, approaching a level which was previously held for several years prior to 1920 (See first and second progress reports of the New England Committee on Marine Piling Investigation, Boston, 1934-'35, 1935-'36).

Hampshire: green heron, bob-white, yellow-throated vireo, grasshopper sparrow, Bartramian sandpiper, and cowbird. Still others scarcely extend north of the northern boundary of Massachusetts (Forbush, '25-'29), either as residents or casual visitants: Acadian flycatcher, orchard oriole, white-eyed vireo, blue-gray gnatcatcher, yellow-breasted chat, mocking bird, golden-winged warbler, prairie warbler. The relative abundance of these species in pre-colonial times in comparison with their present condition is largely conjectural. The elimination of the wild turkey can be laid to man, but another striking disappearance from New England is that of the dickcissel, a bird having no direct food relationship to man. It is characteristic of the Great Plains region, extending westward to the Rocky Mountains: Forbush states that it "formerly bred on the Atlantic slope from Massachusetts to South Carolina and Georgia, but [is] now very rare or casual in that region." Nuttall noted that it was common in eastern Massachusetts in the early 1800's. It is not improbable that the tendency indicated here has had some effect upon the ranges and relative abundance of many other animals whose optimum living conditions are found far to the south and west.

ARCHAEOLOGICAL EVIDENCE

With a view to finding whether there have been changes in the aboriginal life of New England which might be interpreted in terms of climatic alteration, the writer has ventured into the archaeological literature touching upon the region. There is excellent proof that the Indians lived here during at least a part of the period of warm water coastal fauna as well as during the time of refrigeration. The finding of the remains of a fish weir set in the glacial clay beneath the shell muds of Boston's Back Bay has been studied and described by Shimer ('18) and Willoughby ('27). Some 3 to 4 feet of the lower section of the shell muds were deposited after the weir was built, and these contain the southern fauna noted by Shimer in his horizon "4a" (see above).

Dr. Paul B. Sears has recently advanced the hypothesis that the Mound Builder cultures of our middle western states may be correlated causally and in point of time with climatic changes in that region. These cultures were based upon the successful growth of maize, and constitute an agricultural development in a region which otherwise had supported a culture based in large measure upon the chase (Shetrone, '20). One of these cultures, the Hopewell, is known to have extended westward to Iowa, and it is suggested that the development came during a period when more arid climates caused an extension of prairie and park-land eastward into Ohio where such types of vegetation now occur

only as relics (Gleason, '23; Sears, '26). Sears ('32) has summarized these suggestions as follows:

"It must be emphasized that whoever the inhabitants of the Ohio valley were at this time, or whence they came, they enjoyed the optimum conditions afforded during post-glacial time for the development of a successful agricultural civilization. Rich and varied soils of glacial origin, abundant game including the bison, open country with numerous groves of useful kinds of wood, streams easily navigable and full of fish, all favored such a development.

"The intrusive¹ character of the highest mound cultures and the subsequent repossession of their lands by Algonkians is exactly what we might expect if the eastward extension of the corn-belt conditions was a significant factor in such mound cultures."

With regard to the timing of these events Sears states: "If we may judge by the persistence of relict vegetation in favorable localities many effects of this dry period . . . may have long outlasted the actual climatic turn toward the more humid conditions of today. This is significant. Although dry conditions were at their maximum about 3000 years back, we must remember that such was their influence that any final assignment of dates for the higher cultures in Ohio up to 900 years ago is not unreasonable" (See also Sears, '32a, '35a, b, '33).

That the "intrusive" nature of the Mound Builder culture was not confined to Ohio is shown by investigations in New York and New England. There is some evidence that the mound-building people themselves reached western New York State (Parker, '20; Ritchie, '32). The aboriginal history of this state has been divided into three periods of Algonkian occupation. The earliest is represented by crude implements, and evidently featured a woodland, hunting culture. The second is characterized as follows by Ritchie ('32, p. 410): "The combination of brachycephaly with such distinctly new elements as clay and steatite pottery, the pipe, grooved ax, polished slates, and marine shell beads has compelled the writer to postulate a southern source for the Second Algonkin culture of New York. These artifacts occur together over much of the south Atlantic as well as the Mississippi-Ohio area . . ." These people also brought agriculture, and are thought to have originated in the region about Chesapeake Bay. "A later phase of this period was certainly influenced by small bodies of mound-building people entering the state through the southwestern counties"; and "The mound influence may be credited with the presence in New York of the

¹Judging by recent attempts at a new classification of these cultures it may be necessary to consider that they were local evolutions rather than intrusions.

following: the platform pipe, stone tubes, bar amulet, boat stone, native pearl beads and considerable copper in the form of axes, spears and beads" (Ritchie, p. 412).

The third period is related to the Iroquois invasion. "The migration [of the Iroquois] into the state through its southwest corner and probably up the Susquehanna from northern Pennsylvania brought them into contact with the Algonkin of the Second Period, and the writer believes that this influence constituted the impetus behind the cultural alterations which differentiate the Third Algonkin Period" (Ritchie, p. 413). "The elbow-type pottery pipe, noted in a crude form from the Second Period, reaches its acme of artistic perfection in the Third . . . The bone harpoon, both unilaterally and bilaterally barbed, recorded only once from a Second Period site, becomes an important implement at this time. There is, however, a total absence of the grooved ax, gouge, plummet, polished slates, ocean shell beads, and copper" (Ritchie, p. 414).

Further references to the intrusive mound cultures are as follows: "One is led to believe that the later Algonkian copied to a large extent the material culture of a more advanced division of the race that came from the south and west, but which after a certain time was either absorbed or unable to maintain itself in the eastern section" (Parker, p. 48); and "Certainly the material culture of the eastern Algonkins seems to have been considerably modified by this culture [mound], just as later New England tribes were modified by the Iroquois. It is quite possible, therefore, that the mound culture people intruded into the hunting grounds of certain Algonkin bands and established themselves" (Parker, p. 94). "The mound-building people seem to have disappeared from New York at or before the time of the coming of the Iroquois into their area of recognized occupation . . . A survey of the earliest Iroquoian sites, especially in western New York, leads us to believe that the earliest Iroquoian immigrants were measurably influenced by the mound-building culture" (Parker, p. 97). It is thought that the Iroquois did not become established in this region until 500 or 600 years ago.

The evidence just outlined suggests that in western New York State, as well as in the Ohio region, an agricultural, somewhat sedentary people who mastered the use of stone and copper for implements and ornaments succeeded a more primitive, apparently non-agricultural, nomadic people whose arts had never been so highly developed. These were in turn succeeded by the war-like Iroquois who, although they remained in large measure agricultural, apparently lost or never acquired many of the arts of their predecessors in the use of stone and copper.

The intrusion of these arts into New England has been remarked upon by several students. "That the eastern Algonkin received a great cultural impetus from the intruding strangers cannot be doubted. We have some realization of this when we note the thinning out of the polished slate objects in eastern New England, southern New York, Pennsylvania and the region north of the St. Lawrence basin . . ." (Parker, pp. 49-50).

The Europeans found the New England Indians culturally divided into two groups (Dixon, '14; Willoughby, '35). Those north of a district approximated by the northern boundary of Massachusetts (Abnaki and Pennacook groups) were mainly woodland hunters although they practiced agriculture to some extent. Their racial affinities were apparently to the north and northwest, and they made extensive use of birch bark for shelters and utensils. The tribes of Massachusetts, Rhode Island, and Connecticut on the other hand were in large measure agricultural and had a rather highly developed social organization. When the Pilgrims first came to Cape Cod these Indians had already, either directly or indirectly, been in contact with European civilization for many years, so that their actual status as a primitive race is difficult to fix (Willoughby, '35).

Willoughby makes a division of Indian history in New England not unlike that of Parker and Ritchie for New York State. He thinks that an early primitive people unacquainted with agriculture was succeeded by a group related culturally or racially to the Mound Builders west of the Appalachians. "The third culture group to occupy New England was probably an outgrowth of the second. The material culture of these later Indians underwent a marked modification during the period of their virtual separation by the Iroquois from their western kindred. Contact with the Iroquois seems to have been in a measure responsible for this, and in later times intercourse with the many European fishing and trading vessels throughout the greater part of the sixteenth century was a strong factor in the deterioration of certain of their native arts" (Willoughby, '35, p. 2). The distinction between a primitive, non-agricultural people ("pre-Algonquian") and later more highly civilized ones ("Old Algonquian") appears open to some question, although a few sites have been found which indicate a primitive culture which did not include pottery; that is, to assume a *consecutive* arrangement of "primitive" and "non-primitive" sites cannot always be done with assurance (See Delabarre, '25).

However, that there was an *evolution* in the native arts during the so-called second period in New England, influenced by western culture,

seems clear. Ritchie suggests (p. 411) that "Shell middens on the Connecticut, Maine and Nova Scotia coasts, apparently related to certain inland sites, probably mark a northward extension of the Second Algonkin occupation of New York, for they contain such characteristic artifacts as stamped pottery, the grooved ax, plummet, broad-bladed projectile points, perforated animal teeth, the bone gorge, and hematite." If this relationship is correct, these people probably brought agriculture to New England, as they did to New York State, and likewise developed their culture further under such partial influence of the Mound Builder civilization as penetrated the east. A tradition of the southern New England Indians as recorded by Roger Williams (1643) was that their corn and beans had been brought from the southwest.

It has been suggested above that the Iroquois invasion had already marked a notable change in the culture of the southern New England Indians before the arrival of the Europeans. Their history seems to have had the same general pattern as that of the Indians of New York State. Possibly following an early primitive hunting culture there came southern peoples who brought agriculture. This was amplified to produce a semi-sedentary group which could live in large villages and have enough leisure to develop a degree of art. The impulses which led to this development apparently came from more southern and western tribes. The establishment of the Iroquois, as noted by Parker, was probably not over 600 years ago, so that we may regard the so-called "Old Algonquian" culture as having persisted nearly or quite into the period of European discovery.

There is considerable archaeological evidence, therefore, of a rise and decline of certain of the Mound Builder cultural influences in New York State which can be correlated with similar changes in the middle west; and in southern New England there is evidence of an evolution of agricultural civilization during approximately the same period as in New York. If the changes in the middle west can be traced to the influence of climatic and vegetational variation, we can properly expect that the same influence was effective in the east. A warmer and drier climate in southern New England would have greatly facilitated primitive agricultural development, since competition between man and the forest for the occupancy of cultivated lands would not have been so rigorous as under earlier or present conditions.

THE PROBLEM OF COASTAL SUBSIDENCE

Attempts to interpret climatic changes on the New England coast are inextricably entangled with the problem of coastal subsidence.

This is especially true of attempts at dating the changes. It is not intended to go into a detailed discussion of this problem here, but a brief statement of it is in order. There seems to be general acceptance of the idea that there has been either a relative rise of the sea with respect to the land, or an actual subsidence of the land, in comparatively recent post-Glacial time. There is, however, considerable controversy as to whether this so-called subsidence is still going on, or whether we must insert into the chronology an indefinite period of stability following the period of subsidence. In the present inquiry it is of interest to know whether the faunal and floristic changes which occurred *during* the period of subsidence were finished at some remote time when sea level is supposed to have become stabilized, or whether the changes have actually approached the present in point of time.

Evidence that subsidence has continued to the present or to very recent times has been gathered from drowned forests and freshwater peat beds, the structure of shore marshes, measurements of tide levels over a period of about 70 years, and the youthful character of rocky shores.

Drowned forests and peat deposits have been described at many sites along the New England-Acadian shore. An account of them was published by Ganong in 1903 for the region of the Bay of Fundy, where they were first described by Dawson (1855) and later by Chalmers (1895). Well-preserved stumps have been found in place more than 30 feet below high tide, and Chalmers found a peat bed 20 feet thick beneath 80 feet of marsh mud. The drowned forests range from these greater depths to more recently extinct ones which now appear between high and low tides (Bartlett, '09; Antevs, '28; Lyon & Goldthwait, '34). In general the wood in these deposits is remarkably well preserved, indicating a relatively recent origin.

An outstanding feature of most of the New England salt marshes is that the underlying peats do not contain a succession of forms representative of high and low tide floras; but the high tide forms are more apt to be found at considerable depths, often underlain by freshwater peat. This situation was interpreted many years ago by Mudge (1858), and later corroborated by Davis ('10; Bastin & Davis, '09) and Johnson ('25), as indicative of deposit during slow submergence of the land. The same conclusion was reached by Nichols ('20), studying the salt marshes of Connecticut. Marshes of the "Fundy type" (Johnson, '25) have been interpreted in the same way (Dawson, 1855; Ganong, '03), although they are formed differently, and composed largely of silt rather than peat. It was Davis's opinion that the submergence has

continued to the present time ('10; Bastin & Davis, '09); and Nichols ('20) and Bartlett ('09) present evidence for the same conclusion. Nichols points out that on a stationary shore no succession of types [fresh to salt] should be apparent in the peat deposits, and that only where the rate of upbuilding exceeds that of submergence could there be a succession in peats similar to the littoral "zoning" of vegetation postulated by Shaler (1886). Since succession of a "retrogressive" or reverse order to this is common on the New England coast, there seems only one explanation: that the coast is subsiding, or at any rate is being invaded by the sea. That the invasion has been slow is shown by the absence of breaks in the deposits of plant parts *in situ*, often through several feet of depth. Furthermore, these "retrogressive" successions appear to have continued to the present time, as indicated by their presence in the most recent deposits. Bartlett has described the recent invasion of *Chamaecyparis* bog by salt marsh at Woods Hole, with fresh-water deposits a foot beneath the surface over a large area of the present marsh. Johnson ('13), on the other hand, cannot agree that such evidence is reliable, and conceives that Bartlett's bog may have reached its present condition by local shrinkage or sinking.

Records of the relationship between the heights of tides or of mean sea level, and certain "fixed" objects on the shore are open to criticism on account of the relative instability of the fixed objects. Frost action, local undermining, and various sorts of human disturbance are likely to cause movement; and since the reputed sinking of our coast line must be extremely slow, even small shifts in these bench marks are likely to greatly affect the comparison. Nevertheless, making due allowance for such factors, John R. Freeman published in 1903 an exhaustive study of the supposed subsidence at Boston. Basing his figures on records made at the dry dock of the Charlestown Navy Yard in 1831, he concluded that during the succeeding 72 years the subsidence had been 0.71 foot. Records from tide gauges at India Wharf showed approximately the same rate of subsidence over a period of 34 years, and calculations of the so-called "Boston base" showed about the same rate over 35 years. Other evidence of this nature, but less precise, comes from records of high storm tides, and from records of the depth of rocks, particularly near Salem (J. H. Sears, 1894).

There remains the evidence from shore lines on rocky coasts. A clear statement of this has been made by Flint ('30, p. 225), and will bear quoting: "The shoreline of Connecticut is in a youthful stage of development. Its status as a shoreline of submergence is indicated by its indented, ria character, and is abundantly proved by facts adduced in

an earlier part of the discussion. Certain abnormalities in its aspect show that the submergence either has stopped but recently or is still in progress. For example, the bedrock along the shore, even on the most exposed promontories, has not been so much as trimmed by wave-erosion. If the sea had been standing long at its present level, the result would have been a cliffing of the headlands even by the relatively small waves generated in a body of water protected from the open sea."

Ranged against this somewhat formidable array of evidence are mainly the studies of D. W. Johnson and his coworkers at various points along the coast, and some recent investigations of the Damariscotta shell heaps. Johnson ('17; '29) has been unwilling to admit of any recent subsidence on the New Jersey coasts or in the district around New York City, and his studies of the development of the beach at Nantasket (Johnson & Reed, '10) also indicate coastal stability. He has also been inclined to discredit much of the botanical evidence of subsidence on the basis of what he calls the "fictitious appearance of changes of level" ('10; '13). These are caused by local modifications in the configuration of the shore line, mostly in the form of tidal scouring and the opening of barrier beaches during great storms. He attributes most of the cited changes in high tide levels to these causes, and not to general subsidence. Another factor emphasized by him to account for submerged peats is the advance of barrier beaches over peat beds resulting in the bending down of the latter to points below sea level.

Goldthwait ('35) has studied the relationship of the Indian shell heaps in the estuary of the Damariscotta River, in Maine, to local water levels; and he has concluded that the shore has been stable for about 1000 years. His reasons are that none of the shell heaps proper are below high tide level as they might be expected to be if submergence has occurred; and that if submergence had occurred a rocky barrier in the estuary below the heaps might have prevented the growth of the oysters. His figure of 1000 years is based upon an estimate of the time it took to build the heaps.

Without making any pretence at finality or expertness in these matters, the present writer is inclined to believe that subsidence has continued to the present or that it has just stopped (See LaForge, '32, pp. 86-7, 102). Most of the evidence for stability brought forward by Johnson is of a negative nature, and it seems that the local physiographic agencies he invokes could operate with equal facility in either direction. If the coast has been stable, then for every case of the invasion of fresh marsh by salt, we ought to find, somewhere on this com-

plex coast, a place where high tide levels had been *lowered* by the formation of barrier beaches, so that fresh marsh could invade salt. Furthermore, if this had been the rule in ages past we should find frequent interchanges between salt and fresh peat in our sections, or at least breaks in the deposits of salt peat. Two of the outstanding features of the New England salt marshes, however, are first the common occurrence of thick beds of marine peat of a homogeneous nature extending to ten feet or more below the present marsh. These beds have been formed largely of plants whose range is only in the upper tide levels where they are reached by salt water but a short part of each day (*Spartina patens* and *Distichlis spicata*). Second, at varying depths under this deposit is commonly found a layer of fresh-water peat which rests on the mineral substratum. Local changes of tide level such as Johnson postulates might account for a small thickness of peat (2 feet or less) made out of the high tide grasses, but not for much greater depths without a general subsidence of the whole bed. The fact that salt peat almost invariably overlies fresh peat argues against the effectiveness of a reverse change such as must have occurred if Johnson's theories are correctly applied (See also Bartlett, '11). Further, these peat deposits have been formed in places where the physiographic changes suggested by Johnson have not always occurred (Davis, '10).

Johnson & Reed's conclusions from a study of Nantasket beach seem to the writer to be open to doubt because of the many uncertain physiographic variables involved. Of somewhat similar nature are Goldthwait's conclusions, but here an ingenious bit of reasoning is involved that should be noted. The great heaps of oyster shells on the Damariscotta estuary are found to be just *above* a narrow gut which has, at ordinary low tide, a depth of not over three feet and a width of about 60 feet. This barrier is composed of large stones. Goldthwait suggests that if the water stood much lower than now it would not have passed so freely up the estuary, and hence the salinity and probably the temperature of the latter would have been altered. If the current estimates of subsidence are true, then only within the past few hundred years could oysters have grown here, and Goldthwait estimates that it took somewhere between 800 and 1800 years to accumulate the shell heaps, prior to the 17th century when Europeans first arrived on the scene. Some physiographic influences do not seem to have been taken into consideration, however, and open the whole matter to question. One is the relative permanence of the rocky bottom of the gut which contains the barrier, and related to it is the possibility of a change in the rate of flow of fresh water from inland sources which would alter the channels of the estuary.

Another would be local modification of tide levels by physiographic changes farther down the estuary.

The rate of submergence has been estimated in a few cases, and although there can be no expectation of precision in the figures, yet their general agreement is significant. Freeman ('03), from his studies of tide and mean sea levels at Boston concluded that about 12 inches per century was not unreasonable. Davis ('10; Bastin & Davis, '09) set it at the same figure after an extensive study of peat sections, and probably influenced also by Freeman's findings. Bartlett ('09), basing his figures on Shaler's estimate of the rate of peat deposit, thought that the submergence at Woods Hole had been about 10 inches per century. Shimer ('18), working from the rate of mud deposit in Back Bay, at Boston, suggested about 8 inches per century.

It seems entirely justifiable, in the light of the above notes, to assume that there has been no serious break in the progress of subsidence at least during the past 2000–3000 years, and that the change has been fairly steady and slow, perhaps not exceeding a foot a century. By the same reasoning we may assume that no period of indefinite length must be inserted between the present time and the last period of warmer climate on the coast. If the approximate close of this warm period may be set, for the Boston region, at the time when the warm water fauna in the Back Bay was superseded by the present fauna characteristic of cooler waters, then the time may be estimated at about 1000 years ago. Taking the whole region into consideration, the change to a cooler climate must have been a gradual one, and its effects can very well have persisted into the 17th century when oysters were far more abundant on the New England coast than they are now, and when the gastropod *Littorina irrorata* was still common in Long Island Sound.

BOTANICAL EVIDENCE

Using the concept of the close correlation between major climatal and vegetational boundaries as a point of departure, the trends in the vegetational development of southern New England contain rather strong evidence of climatic change. One of the most significant correlations ever adduced between these boundaries is that worked out by Transeau ('05) for the ratio of precipitation to evaporation. A map of isoclimatic lines drawn up from this ratio was found to correspond remarkably well with the configuration of forest types in eastern North America. The correlation was somewhat improved by Livingston and Shreve ('21) with the insertion of a "duration factor" for the length of the average frostless season, and was further refined when a period of

30 days prior to the average frostless season was also involved. The isoclimatic line for the ratio value of 0.110 is found to follow very closely the southern limit of the northern coniferous forest in New England.¹ A glance at the map of precipitation-evaporation ratios shows, however, that the area for values *below* 0.110 in reality sends a long tongue eastward into southern New England which would be more noticeable if the line turned southward along the Appalachian Mountains. This it unquestionably does although the map fails to indicate it due to lack of data from this region. If a warmer and drier climate should develop this boundary could be expected to move northward much as the eastern boundary of the prairie must have moved eastward in the Ohio valley during the "xerothermic" period in that region.²

The apparent progressive elimination of the southern hickories and walnuts from central New England, and the tendency for southern hardwoods generally to be replaced by northern hardwoods and hemlock, are indications of a southward movement of climatic boundaries. Although part of the vegetational change seems to have happened during historic times, yet the climatic influences may have occurred long before, and the oak-chestnut-hickory forest was merely persisting,³ as Bromley suggests, and has not been able to cope with exploitation by Europeans except on the drier sites. If we thus postulate a warmer and drier climate for this region in comparatively recent time, it is necessary to assume that it was intrusive following the amelioration of glacial climate, and that there may have been more than one intrusion. We have at present little evidence for similar southward shifts in other boundaries such as that between the spruce-fir forests and the northern hardwoods, but these can be expected. There is some indication of local retreat of the coniferous forests at the Straits of Belle Isle (Fernald, '11); and Abbe ('36) has suggested that the isolation of some species on the northeastern coast of Labrador may be related to recent changes of climate.

¹A recent classification of North American climates by Thornthwaite ('31) on the basis of temperature efficiency offers a fairly good correlation with vegetational boundaries also (See Nichols, '35, pp. 418-19).

²It is of interest in this connection that Gleason did not think the effects of the xerothermic climate were felt to the eastward of the Appalachians, nor in the Ozark uplands to the southwest. His conception of the consequent forest migrations apparently did not involve these regions. The vegetation of the Ozarks, however, has been studied extensively by Palmer ('21) and later by Palmer & Steyermark ('35), who find abundant evidence of prairie expansion and the movement of forest boundaries within comparatively recent geologic time.

³This tendency on the part of species and vegetation types to persist, or "lag," after conditions have become generally adverse to them has been noted in several lines of inquiry. For discussions of it see Cowles, '01, pp. 79 and 179; Fernald, '25; Clements, '34; Rübél, '35.

As noted above there is some evidence that the white pine was abundant in the pre-colonial forests, and that it passed through a period of decline during the early days of the settlements. Its meteoric rise to prominence in the abandoned fields of the last century can probably be laid to its habit of prolific seeding. The heavier fruited hickories and walnuts with their associates among the oaks could not do this once their sprouts had been removed from pastures and cultivated lands. It is possible to look upon the white pine as a relic of a warmer and drier climate, along with the hickories and their sprout hardwood associates. Unlike the latter, however, it had a new opportunity when the opening of western lands started the decline of New England agriculture, and a new expansion of its habitat appeared in fields abandoned and ready for its seed. Its prosperity is doomed to be short-lived if we may judge by the course of succession now seen in old field stands; and unless new openings are made on a large scale it will probably take the minor place commonly assigned to it in the hemlock-northern hardwood forest, or have a local abundance on very dry soils.

Soils, topography, and local climates in New England are so varied that no matter which way large vegetation boundaries might move, remnants of their former arrangement would be almost certain to survive in localities made favorable by special conditions. The southern remnants of northern vegetation left when the post-Glacial climates retreated have long been objects of study, particularly on the mountains and in bogs. The bogs, usually dominated by black or red spruce, are of common occurrence in most of the northern hardwood region and far southward into the sprout hardwood country. The coastal expression of the bog vegetation in southern New England is in the dominance of the southern white cedar, *Chamaecyparis thyoides*. Nichols has studied these habitats in upland southeastern Connecticut ('13, p. 99), and concluded that the cedar invaded the spruce bogs in comparatively recent geologic time. There is some indication that the white cedar has enjoyed in rather recent times a happier existence in southern New England. Bartlett studied a *Chamaecyparis* bog at Woods Hole, Massachusetts, and has this to say of the cedars: "Some of them, between three and four feet in diameter, were larger than any trees of this species now found in the vicinity of Woods Hole. The wood is still solid and wonderfully preserved"; and "Soundings in this part of the bog [the modern part] show that its history as a *Chamaecyparis* bog has been unbroken. It has never been submerged below sea level, for there is no stratification of the peat which would indicate this. In recent times, however, there have been no trees in this part of the bog as large as those found at

depths of three or four feet, which correspond in age to those exposed in the peat at the edge of the salt marsh" (Bartlett, '09). Although a correlation between the above two sets of observations may be proved impossible, yet there is the suggestion that the southern coast white cedar has intruded into our bogs, particularly on the higher lands, within comparatively recent time, and that it may have passed an optimum on the coast.

There is some evidence that the Island of Nantucket "had many more forest-covered areas, when first patented, than at present, but historic and botanic evidence show that the larger portion of the main island was treeless" (Harshberger, '14). Yet there is also evidence that large oak forests formerly grew there, and a section from a large oak stump on the island is deposited in the Botanical Museum at Harvard (See Wilder, 1894).

A period of pronounced desiccation has been noted in sections of peat deposits on the New England coasts. One phase of this evidence was cited by William C. Alden, based upon a personal communication from C. A. Davis: "Certain fresh water peat beds on the New England coast that are now below sea level supported a dense forest of large white pines. These beds are widely enough distributed to warrant the assumption that in the comparatively recent time in which they were formed, the climate was drier than now for a time long enough to permit the development of two or three generations of these long-lived trees, not less than 500 years, and possibly twice as long. Under existing climate, the white pine has not been observed growing in dense old forest on peat deposits although often observed as an occasional constituent of the swamp forests" ('10, p. 363).

From a bog at Rockwood Park, near St. John, New Brunswick, G. F. Matthew described the following section: "After the sea withdrew from this valley a small pond was left which gradually passed into the condition of a marsh from the growth of grasses and sedges along its borders. The marsh changed to a peat-bog and continued thus for a length of time; eventually, however, the peat disappeared and was replaced by a brown mould or humus, forming a bed nearly a foot thick. Thus conditions favourable to the growth of peat had disappeared and a forest had replaced the peat-bog. The forest, of which this humus was the soil and débris, contained numbers of hardwood trees, and would be the result of a warmer and drier climate taking the place of the moist and cool one which had encouraged the growth of peat. . . . This mild climate, however, did not last long, for the Rockwood bog area was soon again invaded by a sphagnous growth and the hardwood forest destroyed.

There was not, however, such a continuous peaty growth as in the earlier peat-bog, as a second mould bed of some importance appears a short distance above the main one, and the oscillating border of the forest from time to time, showed that the wet climate was not so persistent as in the earlier peat-bog. In the closing stages of the growth of the bog, however, we note that the peat was encroaching on the forest growth around the margin of the bog, which would show that there would not be any amelioration of climate in later years, but rather that there had been a tendency to a moister and cooler climate" ('10, p. 380).

Dachnowski-Stokes has described a similar formation at the Lubec "heath" in southeastern Maine, and has summarized this and other findings as follows: "Toward the bottom appears a buried forest of trees consisting of stumps with numerous roots. . . . The layer is about $1\frac{1}{2}$ feet thick and seems to be present over the entire peat area. The specimens examined were derived from pine, tamarack, spruce, and possibly fir. A similar basal layer of woody peat appears to prevail in the heaths of Veazie and Denbo, at Jonesport, Trescott, Columbia Falls, Pushaw Lake, and Herman Center, and the abundance of roots and stumps has been reported also for the peat deposits of northeastern Canada. The recent account of Auer ['27 (see also '30)] describes layers of stumps at the bottom of cross sections in peat deposits which are being cut away and exposed by the action of the waves in the Gulf of St. Lawrence. As layers of woody peat are present also in peat areas farther inland, it is logical to assume an extensive development of forests, spreading over wide stretches of country under conditions of environment which no longer exist. The climate, and probably coastal marine currents of this period, must have been warmer. The whole region must have passed into a drier stage throughout, and climatic conditions must have set in that were in consequence more continental and southerly in character than it is now in Maine" ('30, pp. 129-30).

Lyon and Goldthwait, in a recent unsuccessful attempt to cross-date trees in drowned forests on the New England coast, made the following observation of interest in the present study. The site was at Ft. Lawrence, Nova Scotia. "Another surprise came when the 24 trees in this collection were identified as representatives of 8 different species. Most of the trees sampled in the lower part of the tract were fir balsam, while those of the inshore and higher area were either pine or hemlock. This suggests a possible change of climate during the advance of the sea from lower to higher levels. Beech, maple, and spruce were represented by only four sections" ('34, p. 608).

F. H. Knowlton, commenting in 1910 on the post-Glacial flora of the

Atlantic coastal plain, could find no large paleontological evidence for a recent warmer climate in that region. However he cites several species (*Taxodium distichum*, *Pinus Taeda*, *Nyssa biflora*, *Ilex Cassine*) of which recently fossilized remains have been found considerably farther north than they now occur ('10, p. 369).

The occurrence of southern species scattered through parts of New England, the Maritime Provinces and Newfoundland has long been the object of study and hypothesis. Many of these plants are isolated from their southern relatives by hundreds of miles, while others represent straggling extensions of range. Approximately 35% of the flora of Newfoundland is of southwestern affinity, either common to the New England-Acadian coast, or to the coast south of Cape Cod (Fernald, '11). Something over 50% of the flora of the Island of Nantucket has a distinctly southern affinity (Bicknell, '19; Fogg, '30). Fernald stated in 1918 that approximately 200 isolated remnants of the more southern coastal plain flora were then known north of New Jersey, some of them extending as far as Newfoundland (Fernald '18). Most of the plants whose ranges have these northern extensions, and certainly those which have been studied in most detail, appear to be of the coastal plain flora; but if we may look upon scattered northern representatives of such a forest complex as that of oak and hickory in the same light, then a large and distinctly non-coastal element may be added to the list of isolations or northeastern extensions. A glance at the northeastern ranges of a great many plants characteristic of the more southern Alleghanian forests will show the same type of scattered distribution in New England and the Maritime Provinces. This was noted many years ago by the geologist C. H. Hitchcock (1874, vol. 1, p. 543), who cited the case of *Rhododendron maximum*, stating that "Its occurrence in insulated swamps suggests a former abundance in intermediate localities, and the presumption of a climate more like that of Pennsylvania, to enable it to flourish within our borders [New Hampshire]." Professor Glover M. Allen ('02, p. 42) has also noted this range, and adds the mountain laurel, *Kalmia latifolia*, the tupelo, *Nyssa sylvatica*, and the climbing fern, *Lygodium palmatum*. One of the more striking disrupted ranges is that of the bur oak, *Quercus macrocarpa*, which is known in eastern New England only in isolated localities such as that in the Penobscot valley near Waterville, Maine (Fernald, 1899).

The current explanation for the northern extension of the coastal plain flora is based upon an ancient emergence of the continental shelf from the sea (Fernald, '11; Nichols, '13, pp. 98-9; Barrell, '15; Martin, '25. A similar hypothesis has recently been applied to the distribution

of land snails by Brooks, '36). This would give the necessary pathway along which plants could migrate as far as Newfoundland. Due to geological exigencies the time of this dispersal is now pushed back to the late Tertiary or to the early parts of the Pleistocene (Fernald, '33; Johnson, '25). But such an explanation is not easily applied to similar northern extensions of upland forest types or individual species. Whether the earlier continuous dispersal which brought about these extensions can be dated far back in the Pleistocene or late Tertiary depends upon whether it was possible for the plants to find refuge during the glaciation somewhere in this region. This is thought to have been the case with isolated remnants of the coastal plain flora in the Maritime Provinces and Newfoundland (Fernald, '33). There is reason to believe that parts of central New England were not covered by the last ice invasion (Bryan, '36); but the climate (Bryan, '28) during this late period must have been exceedingly rigorous, and it seems impossible that such southern plants as *Rhododendron maximum* and *Nyssa sylvatica* could have survived in upland regions between lobes of the ice, far removed from any ameliorating influence which the sea coast may have had upon local climates. Even in areas near the sea there is evidence of intense frost action in deposits of earth which do not appear to have been directly disturbed by the last ice. A northward extension of warm climates into New England in post-Glacial time, with a subsequent partial retreat of the same would do away with the necessity for such a long and hazardous persistence of southern forest species as is suggested above. However, even though we place the original dispersal of these species at a remote period, their present scattered and disrupted northern ranges can be interpreted in terms of a retreating warmer climate within comparatively recent time. This hypothesis gathers force with corroborative evidence for such a climatic change from several different lines of inquiry.

A discussion of the possible causes for this change of climate is beyond the scope of the present paper. Most of the theories expressed by the students of the coastal fauna have been in terms of changes in the courses of local warm or cold ocean currents, these in turn brought about by elevation or subsidence of shore lines and the continental shelf (Verrill, 1874; Ganong, 1890; Upham, 1892). It is notable that the time estimate given above is consistent with recent findings in the old Norse settlements in Greenland (Hovgaard, '25; Nörlund, '24). These studies have established beyond question the fact that when the Norsemen first went to Greenland the shores were remarkably free of ice and the ground was deeply thawed for a portion of each year. Coffins buried

to a depth of several feet are found to have been penetrated by the roots of plants. At this time the Eskimo had retreated to the northward, although there were evidences that they had formerly lived on the ground occupied by the settlements. The change which occurred has been admirably summarized by Brooks ('26, p. 399) as follows: "But in the second half of this century [the 10th] the climate was already deteriorating, and about A.D. 1000 there came a foretaste of the coming ice. After this, conditions apparently improved slightly, and the colony appears to have prospered during most of the eleventh and twelfth centuries. Towards the close of the twelfth century deterioration again set in, and ice conditions rapidly became very bad. The summer thaw became shorter and shorter, and about A.D. 1400 the ground became permanently frozen. Communication with the mother-country was broken, life became too hard to bear, and the colonies finally perished."

Willoughby has already pointed out that the warm period on the New England coast which obtained when the ancient Indian fish weir was built in the Boston district can be correlated with the latest warm era in the middle western states postulated by Sears. The latter placed the climax of this era about 3000 years ago, as noted above, with a rather long subsequent period of "tapering off" in which effects were probably felt as late as 900 A.D. Similarly, there is evidence for a drier, and perhaps warmer climate in northern Europe during approximately the same time (Godwin, '34; Antevs, '25).¹

Whether or not all these changes were due to the same set of causes, they appear to have been fairly coincident in time, and to have been effective throughout northeastern North America, northern Europe, and about the north Atlantic generally.

¹Smaller variations in climate have been studied from various viewpoints and shown to be, at least in part, of periodic occurrence. These variations all appear to be of a smaller order of magnitude than those discussed in the present paper, but should prove to be of considerable significance for many phases of forest management. Thus Kincer ('33) has shown that during the past 50-75 years there has been a slight but steady rise in temperature throughout temperate North America; and that for one station at New Haven, Conn., for which a long record was available (153 years), a former upward trend culminated about 120 years ago and was followed by a decline. This is compared with a somewhat similar curve for Copenhagen, Denmark, where a record of 134 years was available showing a peak about 100 years ago. Rainfall cycles of short period duration have been noted by Pack ('33) and Kincer ('34), but trends as long as those noted for temperature have not appeared. Lyon ('36) has analyzed tree ring growth in the hemlock (*Tsuga canadensis*) in New England, and has shown that notable periods of physiological dryness have occurred during the past 3 centuries, but he does not detect any cyclic effects. On the other hand cyclic changes are clearly indicated by tree ring studies in southwestern United States (See Douglas, '19, '28).

SUMMARY

The writer is fully aware that the evidence presented above is not all of equal value, and that there may be numerous errors scattered through it. This is particularly the case with regard to timing and sequences. None-the-less it has seemed worth while to gather it into one place, rather to stimulate inquiry than to arrive at conclusions.

Investigations along several lines have produced evidence of changes in general living conditions in New England and adjacent New York during the past 3000 years, with effects lasting into more recent time. (1) A "Virginian" element in the marine invertebrate fauna of the New England-Acadian coast has long been recognized, and there is abundant evidence that it was much more widely distributed in recent geologic time. Its remnants have persisted to modern times in areas especially suitable to them. (2) It is clear that Indians lived in southern New England during at least a part of the period of warm water coastal fauna. The northern boundary for the southern, more agricultural aborigines of New England was roughly coincident with the probable former northern boundary of the oak-hickory-chestnut forests, that is, northern Massachusetts-southern New Hampshire and Vermont. There is reason to believe that these southern New England Indians came from the southwest, possibly superseding an earlier nomadic, hunting people. They developed their maize culture apparently under the strong influence of peoples to the southwest of them, and under that of the agricultural Mound Builders of the middle west. This culture seems to have persisted to the time of the Iroquois invasion, probably not more than 600 years ago. Its evolution is roughly coincident with that of the Mound Builders, and might be interpreted as due to an advance toward the northeastward of conditions suitable to the easy cultivation of maize.

(3) The ecotone between the northern and southern hardwood forests appears to be moving southward, with possible attendant effects upon other forest boundaries. (4) Numerous woodland plants common to the more southern Appalachians have a scattered distribution in the uplands of New England, indicating a former, more continuous range. (5) White oak-hickory forests in restricted tracts of the Hudson Highlands have a structure characteristic of regions farther west. (6) The coast white cedar of the southern New England region, characteristic of the Atlantic coastal plain farther south, formerly grew to larger size in our region than it does now, as shown in peat bogs. (7) There is some evidence that oak trees of large size formerly grew on the island of Nantucket. (8) The presence of the remains of white pine and hardwood forests in peat deposits along the New England-Acadian coast

suggests a period of desiccation in comparatively recent times, and (9) certain drowned forests indicate a succession from fir to hardwood types in the lower part of their sections. (10) There is indication that some of the coastal plain trees had a wider range northward in comparatively recent time, as shown by recently fossilized remains in New Jersey.

From this body of evidence we may infer that a warmer and drier climate has occurred in New England within the past 3000 years. The trend since the peak of the warm dry era has been in general toward the cooler and more moist, but probably with minor variations in the opposite direction. There is evidence, further, that the warm dry climate was so recent that the effects of it are still with us in the form of disrupted ranges for southern animals, plants, and forest types. Judging by various estimates related to the rate of subsidence and of peat deposition at the shore, it is thought that the warm water fauna was still abundant on our coast about 1000 years ago, a figure which places the warm period in general coincidence with similar eras in the middle western states, in northern Europe, and in Greenland.

It is suggested that any plan for the utilization of our natural woodlands in southern New England and adjacent New York, involving as it does several generations of long-lived, slow-growing trees, should take this trend into consideration. If the climatic trend continues toward a cooler, more humid condition, or even if it remains for a time as it is, we may expect the oak-hickory and chestnut oak associations to be further restricted in area and in timber value. We may expect the northern hardwood-hemlock forest to develop greater mesophytism and to occupy a somewhat larger area than it now does, not only advancing laterally but also invading the lands within its present range which have been heretofore edaphically unsuited to it. In silvicultural planning for most of southern New England and adjacent New York initial decisions must frequently be made with regard to the ultimate, relative economic advantages of the sprout hardwoods such as white, black, and chestnut oaks, the hickories, and the tulip-tree, as against the more northern hardwoods such as sugar maple, red oak, the birches, beech, and white ash. This study suggests that the decisions should be tempered by the probability that the sprout hardwoods are persisting here under a set of conditions which have tended to become fundamentally adverse to them, and that in the normal course of succession they will be greatly restricted or eliminated over large areas.

The writer wishes to express his appreciation of the invaluable suggestions given by a number of persons during the course of this study. These gentlemen have not always agreed with his opinions and tentative

conclusions, especially with regard to the many controversial and speculative matters touched upon, but their rigorous discussion and criticism have been most helpful and stimulating. Particular thanks are due to Prof. Kirk Bryan, Prof. I. W. Bailey, Prof. M. L. Fernald, Prof. Glover M. Allen, Mr. W. J. Clench, and Mr. William Darrah, all of Harvard University at Cambridge; to Mr. A. C. Cline, Dr. P. R. Gast, and Mr. N. W. Hosley of the Harvard Forest at Petersham, Mass.; to Dr. C. F. Brooks, Director of the Blue Hill Meteorological Observatory of Harvard; to Dr. G. E. Nichols and Dr. H. J. Lutz of Yale University; to Mr. Douglas S. Byers and Mr. Frederick Johnson of the Museum of American Archaeology at Phillips Andover Academy; and to Mr. H. H. Tryon and Mr. H. L. Mitchell of the Black Rock Forest at Cornwall-on-Hudson, N. Y.

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ARNOLD ARBORETUM,
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STUDIES IN THEACEAE. II CLEYERA

CLARENCE E. KOBUSKI

With plate 201

THE ASIATIC GENUS *CLEYERA*, first described by Thunberg in his Nov. Gen. 3: 69. 1783, was named in honor of the physician and botanist Andrew Cleyer, Dutch Director of Commerce during the years 1683–88. Thunberg described a single species and based his description on plants growing near Nagasaki, Japan.

Unfortunately this description was based upon two shrubs as a casual examination of the type indicates. Nearly filling the sheet is an ample specimen of *Cleyera japonica*, while in the upper right corner is a fragment or a near fragment of *Ternstroemia gymnanthera* (W. & A.) Sprague.

Thunberg named "Mokohf" or "Mukohf" of Kaempfer (Amoen. Exot. Fasc. V. p. 873, fig. p. 774. 1712) as a synonym of his new *Cleyera japonica*. Not realizing he was working with two distinct genera of the Theaceae, Thunberg, nine years later noticing the discrepancy mentioned above, came to the conclusion that *Cleyera* was congeneric with *Ternstroemia* and transferred his *Cleyera japonica* to *Ternstroemia* under the name *T. japonica*.

In 1841, Siebold & Zuccarini took up the original name *Cleyera*. They drew attention to the fact that Thunberg undoubtedly did have the two distinct elements in hand when he first described *Cleyera*. At the same time, however they emended his description and pointed out that careful study showed that regardless of what material Thunberg had, his actual generic description was based on the specimen of *Cleyera* and could refer only to *Cleyera*. True enough, in the specific description, the leaf arrangement refers to *T. japonica* (*T. gymnanthera* Sprague). However, this does not affect the status of the genus. They cleared up the whole matter and treated in detail both original elements under their respective genera giving the specific epithet "japonica" to both. Recently, Sprague realizing that *T. japonica* could not be retained, made the combination *T. gymnanthera* (W. & A.) Sprague.

With Siebold & Zuccarini's work confusion should have ended because their treatment of the whole subject seems very clear and quite final. Sprague's treatment of the generic status of *Cleyera* in Jour. Bot. 41: 17, 83 (1923) did much to clear up the whole situation and probably directly or indirectly, caused the name *Cleyera* to be placed on the list of "*nomina conservanda*" by the International Congress of 1935.

Szyszyłowicz in his treatment of *Cleyera* in Engler & Prantl, Nat. Pflanzenfam. III. Abt. 6: 189 (1893) placed the genus under *Eurya* as a section. In a later treatment in the same publication ed. 2, 21: 147 (1925) Melchior made *Cleyera* a subgenus of *Eurya*. Since that time botanists have vacillated between the use of the names *Eurya* and *Cleyera*. However, *Cleyera* is so markedly different from *Eurya* in character that even though students used the name *Eurya*, they were always conscious of the distinct lines of separation.

Other names applied to the genus were *Tristylidium* Turczaninow (in Bull. Soc. Nat. Moscow, 31: 247. 1858) as interpreted by Merrill (in Philipp. Jour. Sci. 13: 148. 1918) and *Sakakia* Nakai, Fl. Sylv. Kor. (17: 77, t. 19. 1928).

Sakakia is clearly a true synonym of *Cleyera*, the name having been proposed by Nakai hoping to clear up the involved synonymy. Evidently unaware of the action taken by the International Congress in the case of *Cleyera*, the Japanese botanists have all rallied to Nakai and wholeheartedly accepted the change. Several new species and varieties have been described under this name. Incidentally, *Sakakia* would have been a fitting name because the plant is generally known in the Japanese empire as "Sakaki."

In the present paper a single species with several varieties is recognized. Because of the many references cited in the synonymy of the species, most of which apply to the genus as well, the author has made it a point to cite in the generic treatment only those references necessary for a clear understanding.

The institutions from which material for this study was borrowed along with the abbreviations used in this paper are as follows: herbarium of the Arnold Arboretum (AA), Gray Herbarium of Harvard University (G), herbarium of the New York Botanical Garden (NY), herbarium of the Natural History Museum, Vienna (V).

Cleyera Thunberg, Nov. Gen. 3: 69 (1783). — Siebold & Zuccarini, Fl. Jap. 153, t. 81 (1841). — Choisy in Mém. Soc. Phys. Hist. Nat. Genève, 1854, 14 (Mém. Ternstroem. 21) (1855); as to sp. 1 & 2 (excl. sp. 3-7). — Bentham & Hooker, Gen. Pl. 1: 183 (1862), in part. —

Sprague in Jour. Bot. **41**: 17, 83 (1923). — Internat. Rules Bot. Nomencl. ed. 3, p. 135 (1935). PLATE 201¹

Tristylum Turczaninow, ex Bentham & Hooker, Gen. Pl. **1**: 183 (1862); as synonym of *Cleyera*. — Merrill in Philipp. Jour. Sci. **13**: 148 (1918).

Eurya § *Cleyera* Szyszylowicz in Engler & Prantl, Nat. Pflanzenfam. III. Abt. **6**: 189 (1893).

Eurya subg. *Cleyera* Melchior in Engler & Prantl, Nat. Pflanzenfam. ed. 2, **21**: 147 (1925).

Sakakia Nakai, Fl. Sylv. Kor. **17**: 77, t. 19 (1928).

Small tree or shrub. Leaves evergreen, alternate, variable in size and shape, from elliptic to elliptic-obovate or obovate, usually cuneate at the base, variable at the apex, petiolate, entire (except in *C. japonica* var. *lipingensis*). Flowers hermaphroditic, solitary or in fascicles in the leaf axils; peduncles thickened at apex, bibracteate, bracts minute, alternate, near apex of peduncle; sepals 5, imbricate, ciliate; petals 5, imbricate, connate at base, reflexed at anthesis; stamens about 25, anthers hispid, biloculate with longitudinal openings; ovary glabrous, 2-3-celled; ovules many; style elongate, bi- or trifid at apex. Fruit baccate, nearly spherical to ovoid-oblong in shape, many-seeded; seeds with thin endosperm and curved embryo.

Cleyera japonica Thunberg, Nov. Gen. **3**: 69 (1783), pro parte; Fl. Jap. **12** (1784), pro parte. — De Candolle, Prodr. **1**: 524 (1824), pro parte. — Siebold & Zuccarini, Fl. Jap. **153**, t. 81 (1841). — Walpers, Repert. Bot. Syst. **1**: 370 (1842). — Siebold & Zuccarini in Abh. Akad. Münch. **4**, abt. **2**: 164 (Fl. Jap. Fam. Nat. **56**) (1845). — Miquel in Ann. Mus. Bot. Lugd.-Bat. **3**: 14 (Prol. Fl. Jap. **202**) (1866). — Franchet & Savatier, Enum. Pl. Jap. **1**: 57 (1875). — Ito & Kaku, Fig. Descript. Pl. Koishikawa Bot. Garden, **2**: t. 18 (1883). — Matsamura, Nippon Skokubutsu meii, **53**, no. 631 (1884). — Tanaka, Useful Pl. Japan, **164** (1895). — Sprague in Jour. Bot. **41**: 17, 83 (1923). — Masamune in Trans. Nat. Hist. Soc. Formosa, **25**: 250 (1935). — Internat. Rules Bot. Nomencl. ed. 3, p. 135 (1935).

Ternstroemia japonica Thunberg in Trans. Linn. Soc. **2**: 335 (1794), pro parte.

Cleyera ochracea De Candolle in Mém. Soc. Phys. Genève, **1**: 43 (Mém. Fam. Ternstroem. **21**) (1822); Prodr. **1**: 524 (1824). — Sprengel, Syst. Veg. **2**: 596 (1825). — G. Don, Gen. Hist. **1**: 566 (1831). — Dyer in Hooker f., Fl. Brit. India, **1**: 283 (1874). — Forbes & Hemsley in Jour. Linn. Soc. Bot. **23**: 76 (1886). — A. E. Osmaston, For. Fl. Kumaon, **42** (1927).

¹PLATE 201. Photograph of generic type in Herbarium Thunberg at the Botanic Museum, Upsala, Sweden. Photograph taken by Prof. Alfred Rehder in 1928.

- Cleyera ochracea* DC. a *Kaempferiana* De Candolle in Mém. Soc. Phys. Genève, 1: 43 (Mém. Fam. Ternstroem. 21) (1822); Prodr. 1: 524 (1824).
- Ternstroemia Lushia* Hamilton ex D. Don, Prodr. Fl. Nepal. 225 (1825).
- Cleyera ochroides* Wallich ex G. Don, Gen. Syst. Bot. 1: 566 (1831).
- Cleyera Lushia* Hamilton ex G. Don, Gen. Syst. Bot. 1: 566 (1831).
- Cleyera Lushia* G. Don var. β *Wallichiana* G. Don, Gen. Syst. Bot. 1: 567 (1831).
- Cleyera Wallichiana* Siebold & Zuccarini, Fl. Jap. 1: 154 (1841).
- Cleyera Mertensiana* Siebold & Zuccarini, l.c. (1841).
- Cleyera ochracea* DC. var. *Lushia* (D. Don) Dyer in Hooker f., Fl. Brit. India, 1: 284 (1874).
- Eurya ochracea* (DC.) Szyszylowicz in Engler & Prantl, Nat. Pflanzenfam. III. Abt. 6: 189 (1893). — Shirasawa, Icon. Ess. For. Jap. 2: t. 53, figs. 18–31 (1908). — Matsamura, Ind. Pl. Jap. 2. pt. 2, 359 (1912). — Rehder & Wilson in Sargent, Pl. Wilson. 2: 399 (1915). — Chun in Mem. Sci. Soc. China, 1: 173 (Trees Shrubs China) (1924). — Melchior in Engler & Prantl, Nat. Pflanzenfam. ed. 2, 21: 147 (1925). — Makino & Tanaka, Man. Fl. Nippon, 357 (1927). — Hozo, Kishiu shokobutsu-shi; Flora Kii Prov. 112 (1929). — Naito & Kajiware in Bull. Kagoshima Imper. Coll. Agric. For. 1: 392 (1934).
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- Freziera ochracea* (DC.) Nakai ex Mori, Enum. Pl. Cor. 251 (1922).
- Sakakia ochracea* (DC.) Nakai, Fl. Sylv. Kor. 17: 77, t. 19 (1928). — Yoshino, Fl. Bitchuensis, 20 (1929). — Masamune in Mem. Fac. Sci. Agric. Taihoku Imper. Univ. 11: no. 4, 302 (Flor. Geobot. Stud. Yakusima) (1934). — Kanehira, Formosan Trees, ed. 3, 469, fig. 429 (1936).

DISTRIBUTION: Japan, Korea, Formosa, China, India.

SPECIMENS EXAMINED:

JAPAN: Near Nagasaki, *Thunberg* (type, photo. in AA); Nagasaki, C. J. Maximowicz in 1863 (AA); alt. 100–1000 m., Mt. Kirishima, Kyushu, Z. Tashiro for E. H. Wilson, June 24, 1927 (AA); “Hizen” K. Sakurai, May 11, 1910 (AA); Yakusima, G. Masamune, Aug. 23, 1924 (NY); temple grounds near Nakatsu-gawa, C. S. Sargent, Oct. 22, 1892 (tree 6–9 m.; probably cultivated) (AA); woods, Tosa Prov., Shihoku, E. H. Wilson, no. 7789, Nov. 17, 1914 (small tree 6–10 m. with black fruit) (AA); Kunigami-gun, Loochoo Isl., R. Kanehira, no. 3241, Jan. 5–6, 1934 (NY); Osima, Nozi-gawa-Yuwan, Loochoo Isl., R. Kanehira, no. 3394, Mar. 22, 1934 (NY); Coll. of Yokohama Nurs. Co. on Loochoo Isl., 1914 (AA).

KOREA. Quelpaert Isl.: common in ravines on south shore,

E. H. Wilson, no. 9490, Nov. 2, 1917 (bush 1:5–2.5 m. with black fruit) (AA); in forests, *U. Faurie*, no. 495, Oct. 1906 (AA); in forests, *U. Faurie*, nos. 1641, 1642, 1643, July 1907 (AA); in forests, *E. Taquet*, no. 591, July 1908; no. 2692, July 1909; no. 2693, Oct. 1909; no. 4136, July 1, 1910 (AA).

CHINA. *Chekiang*: open thickets, Sui-an hsien, *Y. L. Keng*, no. 797, July 15, 1927 (AA); shady woods, Tung-yang hsien, alt. 450 m., *Y. L. Keng*, no. 932, Aug. 1, 1927 (evergreen shrub) (AA); locality lacking, *S. Chen*, no. 1546, June 1933 (AA); Tienmushan, *T. N. Liou*, no. L. 3, July 22, 1930 (NY); alongside stream, Tai-shun, *Y. L. Keng*, no. 287, Aug. 4, 1926 (glabrous evergreen tree) (AA). *Fukien*: under dense wood, northern part of province, alt. 1000 m., *R. C. Ching*, no. 2279, Aug. 5, 1924 (tree 10 m.) (AA, V). *An hwei*: common in woods along stream, S. Chemen, alt. 250 m., *R. C. Ching*, no. 3207, Aug. 13, 1925 (small tree, 12 m. with smooth gray bark) (AA); in wood, Whang shan, alt. 450 m., *R. C. Ching*, no. 2899, July 5, 1925 (shrub 6 m. high with smooth gray bark, buds purplish green) (AA). *Kiangsu*: in thickets, Hai Wei, S. I-Shingon, near border of Chekiang, alt. 200 m., *R. C. Ching & Tso*, no. 512, May 17, 1926 (small shrub of stately form, 3 m. tall with gray bark; flowers nodding, petals amber) (AA); mountainous thickets, Ching-shan, I-shing, *Y. L. Keng*, no. 2649, Aug. 26, 1929 (small evergreen tree, 3 m. with dark grey smooth bark) (AA). *Kiangsi*: along stream in partial shade, Kuling, alt. 1000 m., *C. Y. Chiao*, no. 18707, July 27, 1928 (NY); Lushan Mts., alt. 700–800 m., *H. H. Chung & S. C. Sun*, no. 646, July 23, 1933 (NY, AA); common, side of streams, Kuling, alt. 1200 m. *E. H. Wilson*, no. 1546, July 28, 1907 (bush 1–2 m.) (AA, G); along roadside, Ta Yeh Tsun, Lu Shan, alt. 800 m., *A. N. Steward & H. C. Cheo*, no. 506, Oct. 22, 1932 (shrub 2 m.) (AA). *Kwangsi*: in thickets, Bin Long, Min Shan, N. Luchen, alt. 1200 m., *R. C. Ching*, no. 6019, June 14, 1928 (small tree with brownish bark, 6 m.; flowers whitish, nodding, scented) (NY). *Yunnan*: exact locality and date lacking, *G. Forrest*, no. 26771 (AA); *G. Forrest*, nos. 16080, 18181, coll. 1917–1919 (AA).

From ancient times this species has been known and revered in the Japanese Empire under the name "Sakaki." It grows wild in the mountainous districts and can be found planted around the homes and about Shinto shrines. It is sometimes called "Mijam Sakaki" meaning "God-of-the-high-mountains." "Tamakushige," a kind of wand, dedicated to the gods has been made from this plant explaining the name "Tree-of-God." According to Siebold & Zuccarini, the Buddhists revere the tree

because their priests maintain it is a species close to the "Sara tree" under which the divine founder of their cult died. The fruit is known in Japan as "Ringan." Medically, I understand, the species is used for dysentery, consumption and for the treatment of mental diseases.

According to Ito & Kaku there are many varieties of this species such as small-leaved, long-leaved and round-leaved. A study of a large amount of material bears out their statement, variation being so great that to definitely separate varieties, to say nothing of species, seems almost hazardous. However, there are some varieties, sometimes localized, that seem worthy of recognition. These are treated below.

KEY TO THE FORM AND VARIETIES

Leaves entire

Leaves variegated forma **tricolor**

Leaves not variegated

Leaves approximately 2 cm. wide or less, not more than 8 cm. long.

Leaves up to 8 cm. long, oblong-lanceolate; Formosan variety var. a. **Hayatai**

Leaves up to 5 cm. long, elliptic; Kwangtung variety var. b. **parvifolia**

Leaves up to 5 cm. wide; up to 15 cm. long.

Larger leaves 10-15 cm. long, generally acuminate at apex; Indian and western Chinese variety ... var. c. **grandiflora**

Larger leaves usually below 10 cm. long, generally obtuse at apex; Formosan variety var. d. **Morii**

Leaves serrate var. e. **lipingensis**

Cleyera japonica Thunberg emend. Sieb. & Zucc. forma **tricolor** (Nicholson), stat. nov.

Cleyera japonica tricolor Nicholson, Ill. Dict. Gard. 1: 342 (1885).

Cleyera japonica var. *tricolor* Hort. ex Miller in Bailey, Cyclop. Amer. Hort. 1: 335 (1900); in Bailey Stand. Cyclop. Hort. 2: 802 (1914).

Eurya latifolia variegata A. Verschaffelt in Exp. Gand. 1862 ex Bull. Fed. Soc. Hort. de Belgique (1887) p. 394.

Cleyera Fortunei Hooker f. in Gard. Chron. 17: 10, fig. 1 (1895); in Bot. Mag. 121: t. 7434 (1895). — Bean, Trees Shrubs Hardy Brit. Isles, ed. 1, 1: 373 (1914).

Cleyera japonica foliis variegatis A. Verschaffelt in Exp. Gand. 1862 ex Bull. Fed. Soc. Hort. de Belgique (1887) p. 394.

SPECIMENS EXAMINED:

HORT. — *G. Nicholson*, no. 1782, July 19, 1880, collected in the Royal Botanic Gardens, Kew (AA). — *M. Gebhardt*, Jan. 16, 1889, collected in a greenhouse on the estate of Count Arnim, Muskau, Silesia (AA).

Both specimens cited above are without flowers or fruit. This sterile

condition seems quite typical of this form. In leaf shape this form is identical with the eastern Chinese specimens giving rise to the belief that China rather than Japan is the place of origin. Hooker also seems to share this belief. The texture of the leaf in this form is much thinner than the typical species, a condition found often in variegated forms and generally associated with absence of chlorophyll in the leaf or parts of the leaf. Hooker (1895) in describing *Cleyera Fortunei* remarked that the species had been in cultivation for nearly thirty years, and until flowers were borne, was thought to be a broadleaved species of *Eurya* (*E. latifolia variegata*) having its young leaves stained with a fiery orange. In Bot. Mag. he states that the leaves are "bright green, variegated with golden yellow and scarlet towards the margins." An ever-green shrub with these color features must be a beautiful sight indeed. One would expect it to be found more often in cultivation than it is. This color variegation in the leaves is the only feature separating the form from the actual species.

***Cleyera japonica* Thunberg emend. Sieb. & Zucc. var. a. Hayatai** (Masamune & Yamamoto), comb. nov.

Sakakia Hayatai Masamune & Yamamoto in Jour. Soc. Trop. Agric. 5: 350 (1933). — Yamamoto in Sylvia, 5: 43, fig. 37 (1934).

DISTRIBUTION: Formosa.

SPECIMENS EXAMINED:

FORMOSA: in monte Buisan, *E. Matsuda*, July 1918 (leaf spec. ex herb. Yamamoto); Noka, prov. Nanto, alt. 2333–2833 m., *E. H. Wilson*, no. 10056 (bush 6–15 ft., fruit black, common) (AA).

Yamamoto during his recent American visit left at the Arnold Arboretum a leaf specimen of *Cleyera japonica* var. *Hayatai* for study. Although no number was listed the leaf undoubtedly was taken from one of the syntypes, both syntypes being collected by Matsuda during July 1918 in the same locality. On Yamamoto's label is the name "*Sakakia canicosae* (Merrill) Yamamoto." No reference to this name could be found in literature. A discussion with Merrill, the parenthetical author, concerning this name brought out the information that the name could be nothing more than an annotation on an herbarium specimen, since Merrill discredits ever describing a species under this name.

Masamune & Yamamoto in describing their species *Sakakia Hayatai* list as synonyms *Cleyera Matsudai* and *Sakakia Matsudai*. The latter synonym was cited "excl. Syn." These two synonyms belong to *Eurya Matsudai* Hayata, a recognized species of *Eurya* at the present time. *Eurya Matsudai* Hayata as described and figured is a true *Eurya*. There is nothing in the description warranting the transfer of *Eurya Matsudai*

to *Sakakia*. Probably a specimen incorrectly labeled *Cleyera Matsudai* Hayata in one of the Formosan herbaria led to the transfer by Masamune to *Sakakia Matsudai*.

***Cleyera japonica* Thunberg emend. Sieb. & Zucc. var. b. *parvifolia*, var. nov.**

A typo recedit foliis ellipticis minoribusque, 3.0–5.5 cm. longis, 1.5–2.0 cm. latis.

DISTRIBUTION: Kwangtung.

SPECIMENS EXAMINED:

KWANGTUNG: dry, level land, roadside, Chun Fa Shu, Sam Kok Shan, Tsungfa-Lungmoon Districts, *W. T. Tsang*, no. 20600 (type), May 29, 1932 (3.5 m. tall, flowers white) (NY); common in meadows and on roadsides, Tung Koo Shan, Tapu District, *W. T. Tsang*, no. 21683 (AA), Sept. 8–29, 1932 (shrub 1.5 m., fruit black) (AA, NY); Loh Fau Shan, *C. O. Levine*, no. 568, Oct. 27–30, 1916 (AA); vicinity of Canton, *C. O. Levine*, no. 1453, Aug. 17, 1917 (AA); dry ground in forest, Naam Kwan Shan, Tsengshing District, *W. T. Tsang*, no. 20323, Apr. 24, 1932 (1.75 m. tall, flowers white) (NY); Loh Fau Shan, *E. D. Merrill*, no. 10686, Aug. 17, 1917 (NY); Pak-wan Cheung, Wai-yeung District, alt. 750 m., *T. M. Tsui*, no. 162, March 1932 (1.5 m. tall, flowers white) (NY).

As *C. japonica* Thunb. var. *grandiflora* (Choisy) Kobuski represents the large form of the typical species so does the variety described above represent the smaller variation. The leaves are quite elliptic, never obovate, at least in the specimens studied. It has the general number of stamens of the genus (24–25) which are hirsute. This variety is confined to the province of Kwangtung.

***Cleyera japonica* Thunberg, emend. Sieb. & Zucc. var. c. *grandiflora* (Wallich ex Choisy), comb. nov.**

Cleyera grandiflora Wallich, Num. List, no. 1461 (1829), nom. nud.

Cleyera grandiflora Wallich ex Choisy in Mém. Soc. Phys. Genève, 1854, 14 (Mém. Ternstroem. 21) (1855).

Cleyera ochnacea DC. var. *grandiflora* (Wallich ex Choisy) Dyer in Hooker's Fl. Brit. Ind. 1: 284 (1874).

Cleyera grandiflora Hooker f. & Thoms. ex Dyer in Hooker's Fl. Brit. Ind. 1: 284 (1874).

DISTRIBUTION: India, Szechuan, Yunnan, Tibet.

SPECIMENS EXAMINED:

SOUTHEASTERN TIBET: Salween Valley at Champutong, Mount Kenyichumpo and region of Champutong, Salween-Irrawadi watershed, alt.

2450 m. *J. F. Rock*, nos. 10225, 10245, coll. in 1923 (woody climber; fls. cream colored) (AA). YUNNAN: data lacking, *G. Forrest*, no. 8424 (AA). EASTERN SZECHUAN: Wushan Hsien, *E. H. Wilson* (Veitch Exped.) no. 2688, Oct. 1900 (AA). INDIA: Khasia, alt. 600 m., *J. D. Hooker & T. Thomson* (probable isotype of *C. grandiflora* Hook. f. & Thoms.) (G.); below Dharmgadh in the Sarju Valley, East Almora, United Provinces, alt. 1500 m., *A. E. Osmaston*, no. 1484, Jan. 26, 1932 (shrub or small tree) (AA); Dindihat to Askot, Almora District, alt. 1500 m., *R. N. Parker*, no. 2047, Jan. 7, 1923 (AA); Upper Burma, *G. Forrest*, no. 27556, coll. 1924-25 (AA); western Nepal, *Bis Ram*, no. 573, June 25, 1929 (AA); Mausmai, Assam, alt. 1200 m. *L. R. Ruse*, no. 145, May 18, 1923 (AA).

Localized in India, western China and Tibet, this variety is distinguished from the species only in its uniformly larger size. Leaf measurement in the specimens studied vary up to a maximum of 15 cm. long and 5.5 cm. wide. The peduncles are sturdier than the normal species, and in a single instance one measuring 2 cm. was found.

This variety was first described as *Cleyera grandiflora* Choisy in 1855. Later, Dyer in Hooker's Fl. Brit. Ind. (1: 284. 1874) reduced Choisy's species to *Cleyera ochracea* var. *grandiflora*. In the same publication Hooker f. & Thomson's species (not of Wallich or Choisy) *Cleyera grandiflora* was described. The synonymy became involved at this point because Hooker f. & Thomson, thinking naturally that their species was different from Choisy's now reduced species, used the same name, *Cleyera grandiflora*. Some of the differences used in separating these two in Hooker's Fl. at that time were: (1) fascicles 2-4 flowered against flowers usually solitary; (2) leaves narrower, more acuminate against leaves oblong, obtusely acuminate; (3) apex of peduncles with two almost obsolete bracts against peduncles with minute alternating bracts. Variation in these characters is, in general, too great to permit separation. As mentioned above, the only basis for even varietal distinction from the species is size.

***Cleyera japonica* Thunberg emend. Sieb. & Zucc. var. d. *Morii* (Yamamoto) Masamune in Trans. Nat. Hist. Soc. Formosa, 25: 250 (1935).**

Eurya ochracea DC. var. *Morii* Yamamoto, Suppl. Icon. Pl. Formos. 3: 40, fig. 13 (1927).

Tristylium ochraceum Merrill var. *Morii* Sasaki, List Pl. Formosa, 294 (1928).

Sakakia Morii (Yamamoto) Yamamoto & Masamune in Jour. Trop. Agric. 2: 34 (1930). — Yamamoto & Mori in Sylvania, 5: 44 (1934). — Kanehira, Formosan Trees, 470 (1936).

DISTRIBUTION: Formosa.

SPECIMENS EXAMINED:

FORMOSA: Tam-sui, *A. Henry*, no. 1468, date lacking (NY); Tam-sui, *R. Oldham*, no. 35, April 1864 (NY); common in forests near Nanwo, Prov. Karenko, *E. H. Wilson*, no. 11117, Nov. 26, 1918 (tree 10 m. high, fruit black) (AA, NY); Kelung, *C. Ford*, no. 27, date lacking (G); Kelung, *O. Warburg*, no. 9975, Jan. 1888 (AA); vicinity of Sozan, *T. Tanaka*, no. 115, June 22, 1929 (AA).

To date this variety has been collected only on the island of Formosa. By Yamamoto it was characterized as having larger and obovate leaves. This size characterization may apply to the Formosan material but hardly to the species as a whole when one considers the Chinese and Indian material. For a generalization, the shape of the leaf might better be designated obovate-elliptic because there is usually a distinct even tapering from the center of the leaf to the base. The obovate character of the apex in this variety is very variable. In some cases, the apex is nearly subrotund, slightly contracted into a very short rounded acumen. In other instances, still obovate, the apex tapers quite abruptly to a point. Finally, in some leaves, the apex appears actually emarginate. The pedicels are quite short, seldom more than 7 mm. long. As a result of the latter, specimens with crowded immature fruits resemble *Ilex rotunda* Thunberg very closely.

Cleyera japonica Thunberg emend. Sieb. & Zucc. var. *e. lipingensis* (Handel-Mazzetti), comb. nov.

Eurya ochracea (DC) Szyszylowicz var. *lipingensis* Handel-Mazzetti in Akad. Anz. Wiss. Wien, 1921, p. 180 (Pl. Nov. Sin. Forts. 13, p. 14) (1921); Symb. Sin. 7: 399 (1931).

Sakakia longicarpa Yamamoto in Jour. Soc. Trop. Agric. 5: 350 (1933).

DISTRIBUTION: Kweichow, Hainan and Formosa.

SPECIMENS EXAMINED:

KWEICHOW: Kutschou et Liping, in silva frondosa prope vicum Dayung, alt. 700 m., *Handel-Mazzetti*, no. 10938 (isotype) July 22, 1917 (tree) (AA); in light woods, *Y. Tsiang*, no. 4133, Jan. 25, 1931, (tree, 4 meters high, bark green, leaves deep green above, pale beneath; fruit blackish) (AA, NY). HAINAN: in woods, alt. 600 m., Yaichow, *F. C. How*, no. 70311, March 6, 1933 (tree 13 m. high with gray bark; leaves light green above, pale green beneath, coriaceous; fruit green when young, black when mature) (AA, NY); heavily wooded ravine, Hung Mo Mt. above Fan Ra, Hung Mo Tung, *McClure & Fung*, no. 751,

August 24, 1929 (NY, AA). FORMOSA: in monte Tsugitakayam, alt. 2100 m., Y. Simada, Oct. 9, 1925 (leaf specimen only) (AA).

This variety is most unusual in the genus because of the serrate leaves. In all other representatives of *Cleyera*, the leaves are entire. Without flower and fruit one naturally would be inclined to place it in the closely related genus *Eurya*. Handel-Mazzetti in drawing up his description, had only a single "wilted" corolla and, judging from the isotype in the Arnold Arboretum, a few immature fruits. Tsiang's specimens in both the Arnold Arboretum and the New York Botanical Garden are sterile. Yamamoto, during his recent American visit, left with me fragments and tracings of some of the Formosan Theaceae. Of his *Sakakia longicarpa* only a leaf specimen is available. However, this leaf is a nearly perfect match with those on Handel-Mazzetti's isotype. Besides leaf serration, Yamamoto lists ciliate calyx lobes and oblong fruit as characters separating his species from *Sakakia ochracea*. This fruit variation is not uncommon in the whole genus and ciliate calyx lobes are considered a good character of *Cleyera japonica*.

At first, having only fragmentary representation from the far removed localities, Yunnan and Formosa, one naturally would be loth to combine the two. Later, when Tsiang's Hainan specimens were studied, the related identity became more of a certainty.

EXCLUDED SPECIES

Cleyera albopunctata (Grisebach) Krug & Urban in Engler, Bot. Jahrb. 21: 537 (1896) = **Ternstroemia albopunctata** Grisebach, Cat. Pl. Cub. 36 (1866).

Cleyera elegans (Tulasne) Choisy in Mém. Soc. Phys. Genève, 14: 110 (1855) = **Freziera elegans** Tulasne in Ann. Sci. Nat. ser. 3, 8: 336 (1847).

Cleyera integrifolia (Benth) Choisy in Mém. Soc. Phys. Genève, 14: 112 (1855) = **Freziera integrifolia** Benth. Pl. Hartweg. 6 (1839).

Cleyera Matsudai Hayata in Sched. Herb. Univ. Imp. Taihoku, no. H. 174, nomen nudum = **Eurya Matsudai** Hayata, Ic. Pl. Formos. 9: 6 (1920).

Cleyera mexicana (Turczaninow) Planchon ex Hemsley, Biol. Centr. Amer. Bot. 1: 93 (1879) = **Freziera** sp.

Cleyera Nimanimae (Tulasne) Krug & Urban in Engler, Bot. Jahrb. 21: 540 (1896) = **Freziera Nimanimae** Tulasne in Ann. Sci. Nat. ser. 3, 8: 338 (1847).

Cleyera serrulata Choisy in Mém. Soc. Phys. Genève, 14: 110 (1855) = **Ternstroemia** ? sp.



CLEYERA JAPONICA THUNBERG

Cleyera siphilitica Choisy in Mém. Soc. Phys. Genève, **14** 110 (1855)
= **Ternstroemia** ? sp.

Cleyera theoides (Swartz) Choisy in Mém. Soc. Phys. Genève, **14**:
110 (1855) = **Freziera theoides** Swartz, Fl. Ind. Occ. 972 (1800).

Sakakia Matsudai (Hayata) Masamune in Jour. Soc. Trop. Agric.
4: 192 (1932) = **Eurya Matsudai** Hayata, Ic. Pl. Formos. **9**: 6
(1920).

HERBARIUM, ARNOLD ARBORETUM,
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NEW NAMES IN TIMONIUS

E. D. MERRILL

IN 1901 Britten¹ called attention to Trimen's² observation that the generic name *Timonius* dates only from 1830, when de Candolle gave a formal generic description and associated this old Rumphian monomial of 1743 with the binomial system, and that rightly this generic name should be superseded by *Nelitris* Gaertner (1788). Gaertner's figure is a representation of the fruit of a *Timonius*, but in his text he confused it with some species of *Eugenia*, this leading to de Candolle's erroneous application of *Nelitris* to a genus of myrtaceous plants, properly *Decaspermum* Forster. *Nelitris* as a genus is typified by *N. Jambosella* Gaertn. = *Timonius Jambosella* Thwaites. *Timonius* (Rumph.) DC. is typified by the Moluccan form originally described by Rumphius and variously known as *T. Rumphii* DC. and as *T. sericeus* (Desf.) K. Schum. The two species are generally considered to be congeneric, but, as Alston³ pointed out Valeton in 1909 considered the Ceylon species to be referable to *Bobea* Gaudich. If this disposition of it be correct and it still be desirable to retain *Bobea* Gaudich. as generically distinct from *Timonius* DC., then doubtless Alston is correct in retaining *Nelitris* Gaertn. in place of *Bobea* Gaudich. In retaining *Nelitris* Gaertn. in this sense Alston states: "Valeton has referred this [*Timonius Jambosella* Thw.] to *Bobea* Gaud. and though *Nelitris* Gaertn. is one of the "nomina rejicienda" of the International Rules I think that it should be adopted in preference to *Bobea* Gaud." As I understand the International Code *Timonius* DC. was protected against replacement by the earlier *Nelitris* Gaertn., but this has no bearing on the case of *Nelitris* Gaudich. versus *Bobea* Gaudich. Britten further called attention to the fact that *Eri-thalis Timon* Spreng. was the first published binomial for the type species of *Timonius*, and in accepting *Nelitris* to replace *Timonius* proposed the new binomial *Nelitris Timon* (Spreng.) Britten.

The genus is largely characteristic of the Malaysian region, with few representatives in Ceylon, Seychelles, Madagascar, Australia, and New Caledonia, about twelve in Micronesia and Polynesia, and twenty-five in

¹Jour. Bot. 39: 69. 1901.

²Fl. Ceyl. 2: 339. 1894.

³ALSTON, A. H. G. in TRIMEN, H. Hand-book of the flora of Ceylon 6: (Suppl.) 151. 1931.

the Philippines. In 1909 Valetton¹ published a critical consideration of the Malaysian species, not including the Philippine ones, thirty-three species being then known to him, and he estimated that a total of about fifty-five species were then known in the entire range of the genus. At the present time a total of about 150 species are known for which there have been published in *Timonius* and in reduced genera about 190 binomials. By far the richest area is New Guinea.

Timonius (Rumphius, 1743) de Candolle (1830) was fortunately conserved by the Vienna Botanical Congress over *Nelitris* Gaertner (1788), *Porocarpus* Gaertner (1791), *Polyphragmon* Desfontaines (1820), *Helospora* Jack (1823), and *Burneya* Chamisso & Schlechtendal (1829), otherwise, as *Nelitris* Gaertner is the oldest generic name, unless it be true that the Ceylon *Timonius jambosella* Thwaites is really a *Bobea*, it would be necessary to transfer from *Timonius* to *Nelitris* approximately 150 binomials, a high percentage of which have been published within the present century. The synonymy of the type species of *Timonius* is as follows:

***Timonius Timon* (Spreng.), comb. nov.**

Erithalis Timon Spreng. Pl. Min. Cogn. Pugil. 1: 18. 1813.

Polyphragmon sericeum Desf. Mém. Mus. Hist. Nat. Paris 6: 6. t. 2. 1820.

Erithalis polygama Forst. var. *timonius* Willd. Sp. Pl. 1: 997. 1798.

Timonius Rumphii DC. Prodr. 4: 461. 1830.

Timonius sericeus K. Schum. Fl. Kaiser-Wilhelmsl. 131. 1889, Bot. Jahrb. 13: 433. 1891; Valetton, Bull. Dep. Agr. Ind. Néerl. 26: 52. 1909; Merr. Interpret. Herb. Amb. 486. 1917.

Nelitris Timon Britten, Jour. Bot. 39: 68. 1901.

Timonius Rumph. Herb. Amb. 3: 216. t. 140. 1743.

The species is recorded from Timor, Banda, Amboina, Ternate, New Guinea, the Solomon Islands, and eastern Australia. *Timonius sericeus* var. *tomentosa* Valetton, Bull. Dep. Agr. Ind. Néerl. 26: 53. 1909 occurs in New Guinea and in Queensland and var. *grandiflora* K. Schum. in K. Schum. & Lauterb. Fl. Deutsch. Schutzgeb. Südsee 568. 1901 in New Guinea. Of the binomials cited above *Timonius Timon* Merr., *Nelitris Timon* Britten, *Erithalis Timon* Spreng., and *Timonius Rumphii* DC. are based in Rumphius' description and illustration of *Timonius* or *Timon*, there being no extant type. *Robinson Pl. Rumph. Amb. 166* from Amboina, the type locality, still known there as *timon* is an excellent representation of the plant Rumphius described and illustrated. *Timonius Rumphii* sensu Wall. List no. 6217, 1832, Hook. f. Fl. Brit.

¹VALETON, T. Beiträge zur Kenntniss der Gattung *Timonius*. Bull. Dep. Agr. Ind. Néerl. 26: 1-61. 1909.

Ind. 3: 127. 1880, non DC., of the Malay Peninsula, is the distinctly different *Timonius Wallichianus* (Korth.) Valeton.

In addition to the above change of name, three additional ones are indicated:

***Timonius octonervius*, nom. nov.**

Timonius ferrugineus Valeton, Bot. Jahrb. 61: 40. 1927, non Merr. 1915.

***Timonius papuanus*, nom. nov.**

Timonius involucratus Valeton, Bot. Jahrb. 61: 41. 1927, non Merr. 1917.

For the two New Guinea species here renamed, Valeton overlooked my earlier use of the same specific names for Bornean species in 1915 and 1917.

***Timonius Ridleyi*, nom. nov.**

Timonius hirsutus Ridl. Jour. Straits Branch Roy. As. Soc. 77: 239. 1918; Fl. Malay Penin. 2: 115. 1923, non Merr. 1917.

Ridley's Malay Peninsula species needs a new name, as one year earlier I had published the same name for a different Bornean species.

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NOTES ON NORTH AMERICAN TREES AND SHRUBS

ERNEST J. PALMER

With two text figures

Carya texana (Le Conte) C. DC. (*C. aquatica* \times *C. Pecan*). In a collection of plants received at the Arboretum several months ago from Mr. B. F. Bush was a fruiting specimen of a hickory, collected near Campbell, Dunklin County, Missouri, by Mr. John H. Kellogg, and distributed as *Carya aquatica*. The mature fruit was quite different from that of the water hickory, and it at once suggested a hybrid between that species and the pecan. No specimens recognized as such a hybrid were found in the herbarium, but upon comparing Mr. Kellogg's specimen with *Carya texana* it was found to agree very closely with certain specimens in the characters of both leaves and fruit. A further examination of all the material of *Carya texana* in the Arboretum herbarium suggests very strongly the probability that this widely distributed but rather rare hickory is in reality a hybrid between the two species referred to above.

Carya texana is found occasionally, though nowhere in abundance, throughout the common range of the water hickory and the pecan, and so far as I am aware nowhere beyond this general range. It is generally known as bitter pecan by the country people, but it is also sometimes called pignut, both of which common names are also applied to other species in the same region, the former to *Carya aquatica* and the latter to *Carya cordiformis*.

The original description of *Hickoria texana* was published by Major John Le Conte in the Proceedings of the Academy of Natural Sciences of Philadelphia, 1853, p. 402, under the title "Description of a new species of Pecane Nut." The author states that he found the plant cultivated in Georgia, but that it is a native of Texas. Amongst the characters pointed out as distinguishing the new species from "the common pecane nut" are the small size of the trees, which it is stated seldom exceeds 10 or 12 feet in height, the smaller size of the leaves and the later date at which they unfold, and particularly the shape of the nut, which is described as ovate and flattened, although protuberant on the sides, and with a rough surface as contrasted with the smooth, cylindrical nuts of the pecan. The description did not say whether the nuts of the trees cultivated in Georgia were bitter or edible, but the fact that they

were in cultivation might indicate the latter. However, in other sections where the tree has been found the fruit is bitter, as the common names indicate.

Both the pecan and the water hickory are amongst the last of the broad-leaved trees to put out their foliage in spring, and from several specimens that I have seen in young leaf, it seems doubtful whether *Carya texana* is more tardy in this respect. The smaller fruit mentioned as characterizing the type plants probably has little diagnostic value, since the nuts of the native pecan vary greatly in size on different trees, and nuts of some of the specimens of *Carya texana* in the Arboretum herbarium are as large as those of almost any native pecan. The small size of the fruiting trees mentioned by the author is not readily accounted for, but this also seems to be quite variable. Sargent in the second edition of the *Manual of the Trees of North America* says that *Carya texana* is sometimes a tree 100 feet high. There are no notes as to size on most of the herbarium specimens, but on the label of one specimen collected by Bush at Columbia, Texas, it is stated that it is from a large tree; while a fruiting specimen collected by Geo. L. Fisher in Chambers County, Texas, is said to be from a shrub only two or three feet high.

The leaves of the water hickory and those of the pecan are quite similar, although there is a tendency for the leaflets to be slightly smaller, narrower, and more numerous in the pecan. The leaves of *Carya texana* are usually indistinguishable in form from those of the water hickory, but in some specimens they more closely resemble those of the pecan. In all three species the leaflets, though variable, are typically lanceolate or ovate-lanceolate, somewhat falcate, long acuminate at the apex, and unsymmetrical at the base in the lateral pairs. The number of leaflets ranges from seven to seventeen in the pecan, eleven to thirteen being most frequent; seven to eleven is the prevailing number in the water hickory, although rarely reduced to five; while in *Carya texana* the number is even more variable, generally being between five and fifteen. The staminate aments in *Carya pecan* are short stalked or nearly sessile, while those of *Carya aquatica* are usually distinctly peduncled. In one specimen of *Carya texana* from Texas the flowering aments are sessile and spring from growth of the season, while in another specimen from Natchez, Mississippi, they are distinctly peduncled and are born on both the new growth and on wood of the previous season. The fruit of *Carya texana* is quite variable in shape and size, as has been stated. In some specimens it is distinctly compressed and with keel-like edges, as in nuts of *Carya aquatica*, while in others it is quadrate or quadrate-cylindric to short elliptic in cross section, and is only slightly

compressed. The nuts in *Carya aquatica* are roughened or irregularly corrugated on the surface, and are of a uniform dark brown color, while those of the pecan are smooth, and red-brown with darker irregular lines. Examination of the fruit from a large series of specimens of *Carya texana* shows a range of variability in these characters between the pecan and the water hickory. In the majority of specimens the fruit approaches more nearly that of the pecan in shape and in the smooth or nearly smooth surface, but in some cases the surface shows distinct signs of wrinkling or roughening, although not so pronounced as in *Carya aquatica*.

The idea that *Carya texana* may be a hybrid does not seem to be an entirely new one, although it has generally been accepted as a distinct species in manuals. Dr. William Trelease in a paper on the Hickories in the 7th Annual Report of the Missouri Botanical Garden (1896), p. 34, suggested that it is probably a hybrid of the pecan, although he did not express an opinion as to the other parent species. But in a later paragraph he referred to a paper by Dr. Charles Mohr in Garden and Forest, 1889, p. 570, in which it is said that crosses between *Carya pecan* and *C. aquatica* are often met with where the two species grow together.

The water hickory is abundant about Campbell, Missouri, where Mr. Kellogg's specimen was found. The pecan also grows in southeastern Missouri, although I have seen no specimens from the immediate vicinity of Campbell. After a full examination of the material available for study, I think that the evidence is abundantly convincing that the bitter pecan, *Carya texana* (Le Conte) C. DC., is a hybrid between *Carya aquatica* and *C. pecan*, and the specimen collected by Mr. Kellogg, no. 27036, near Campbell, Dunklin County, Missouri, Sept. 4, 1935 is referred to this hybrid.

Mr. Kellogg's discovery of *Carya texana* in Missouri extends its range greatly, and also adds another interesting tree to the flora of the state. Besides this new record, *Carya texana* is represented in the herbarium of the Arnold Arboretum by specimens from Arkansas, Mississippi, Louisiana, and Texas, and the nearest station to the Missouri locality is Van Buren, Arkansas, more than three hundred miles distant.

× **Carya Demareei**, *hyb. nov.* (*C. cordiformis* × *C. ovalis*). *Hybrida intermedia inter parentes*; folia 5-9, plerumque 7, lanceolata vel ovato-lanceolata, falcata; fructus obovatus vel oblongo-ovatus, exocarpio tenui 1.5-2.5 mm. crasso.

ARKANSAS: flat woods near Piggott, Clay Co., *Delzie Demaree*, Aug. 11, 1927 (type); low woods, foot of Crowleys Ridge, near Jonesboro, Craighead Co., *E. J. Palmer*, no. 26689, Oct. 21, 1924. Specimens in the herbarium of the Arnold Arboretum.

The intermediate character of the foliage, fruit, and winter buds of this tree, which is described from specimens collected by Dr. Delzie Demaree in Clay County, Arkansas, clearly indicates that it is a hybrid between the bitternut and the small-fruited hickory. The number of leaflets ranges from five to nine, but is usually seven as in *Carya ovalis*; while the small, tightly compressed winter-buds resemble more closely those of *Carya cordiformis*. The fruit on the type specimen is quite similar to that of *C. cordiformis* in the very thin, smooth involucre, although in the shape of the nut and in the less prominently winged sutures of the involucre there is an approach to the other parent species. In a specimen collected by the writer in Craighead County, Arkansas, which is apparently the same hybrid, the involucre and shell are slightly thicker and the sutural ridges are more prominent.

Carya Demareei has so far been recognized only in northeastern Arkansas, where it grows in low or flat woods in close proximity to the supposed parent species, but it may be expected to occur in other sections where these species are found.

Quercus Nuttallii E. J. Palmer.¹ (Text figure 1.) Since the publication of the description of this species many inquiries about it have been received and a number of specimens have been sent in to the herbarium by collectors and foresters. From these reports it appears that the tree is much more abundant in some sections than I was aware of at the time it was described. One correspondent states that it is one of the important timber trees in the lowlands of the Yazoo delta and the lower Mississippi valley, and that it is so different from any of the other oaks that the loggers and lumbermen readily distinguish it. Frequent requests have been received for the published description, but as no reprints of it were made at the time and as the number of the Journal in which it appeared has long been exhausted, it is now impossible to supply it. Recently what appears to be a small-fruited form or variety of *Quercus Nuttallii* has been discovered, and as no illustration of the typical form has been published previously, a sketch of the leaves and fruit of both this and the new variety described below are now published, which it is hoped will facilitate their identification.

Quercus Nuttallii var. *cachensis*, var. nov. A typo differt fructu minore 16–18 mm. longo 12–16 mm. lato, cupula brevior glandem circiter 1/3 includente. (Text figure 2.)

ARKANSAS: bottoms of Cache River in overflow (large trees, bark like *Q. Phellos*), Cotton Plant, Woodruff Co., *D. Demaree*, no. 10865 (type), Aug. 29, 1934; low wet woods about 2 mi. west of Wheatley,

¹Jour. Arnold Arb. 8: 52 (1927).

Moore Co. (2 ft. D. B. H., just cut for logs — from top of tree), *D. Demaree*, no. 10910, Sept. 1, 1934; very low ground, Clarendon, Monroe Co. (3 ft. D. B. H.), Clarendon, Monroe Co., *D. Demaree*, no. 10917, Sept. 2, 1934; Fulton (Hempstead Co.), *John H. Kellogg*, Aug. 31, 1910.



FIGURE 1. *QUERCUS NUTTALLII* E. J. Palmer. $\times 3/5$

In the specimen that is taken as the type of this variety and in others collected in the same vicinity, the fruit which is short-oblong or depressed-conic, with the nut about one-third enclosed in the shallow cup, has considerable resemblance to that of *Quercus palustris*, and suggests the possibility of a hybrid between *Quercus Nuttallii* and that species. But since the acorns in all respects except their shape and size indicate a close relationship to the latter species, and since the leaves and winter-buds are quite like those of the type, it seems best to treat it as a variety of *Quercus Nuttallii*.

Typical specimens of *Quercus Nuttallii* are growing in the immediate vicinity of the new variety and the species is not uncommon in the region. *Quercus palustris* is rather rare in Arkansas, and I have not seen specimens from Woodruff, Moore, or Monroe counties, although it is occasionally found in northeastern Arkansas.



FIGURE 2. *QUERCUS NUTTALLII* var. *CACHENSIS* E. J. Palmer. $\times 3/5$

Quercus breviloba (Torr.) Sarg. (*Q. annulata* Buckley, 1861, not J. E. Smith, 1819). In an interesting collection of plants made by Mr. George M. Merrill in the Platt National Park, near Sulphur, Oklahoma, were several specimens of *Quercus breviloba*, a species characteristic of the limestone regions of central Texas, and not previously known north of that state. The discovery of this shrubby oak in Oklahoma not only extends its known range northward, but it also adds a very interesting species to the flora of the state and furnishes another example of the incursion of species characteristic of the Edwards Plateau of Texas into the Arbuckle Mountain region, most of which is underlain by a lime-

stone formation somewhat similar in character to that found south of Red River, although it is much older geologically.¹

Another specimen in the same collection is an evident hybrid between *Quercus breviloba* and the post oak (*Quercus stellata*). According to notes furnished by Mr. Merrill, several small trees were found growing in a dry, exposed situation, where *Quercus breviloba* is predominant, and with *Q. stellata* in the immediate vicinity. The trees are 10 to 15 feet in height and have rough bark, similar to that of the post oak. A specimen with immature fruit was collected by the writer near Strawn, Texas, and one with leaves only, near Brownwood, Texas, several years ago, both of which appear from their characters and association to belong to this hybrid. As Mr. Merrill's specimen has mature fruit, it may be taken as the type.

× **Quercus Mahoni**, *hyb. nov.* (*Q. breviloba* × *Q. stellata*). *Hybrida intermedia inter parentes; frutex robustus vel arbor minor ad 2–3 m. alta, foliis obovatis vel oblongo-obovatis lobatis rotundis inaequalibus 4–9 cm. longis 3–5 cm. latis.*

OKLAHOMA: Platt National Park, Sulphur, *G. M. Merrill*, no. 1634 (type), Oct. 28, 1935. TEXAS: Strawn, Palopinto Co., *E. J. Palmer*, no. 14267, June 27, 1918; Brownwood, Brown Co., *E. J. Palmer*, no. 29501, Nov. 1, 1925. All specimens in the herbarium of Arnold Arboretum, and isotype in the herbarium of the Platt National Park, Sulphur, Okla. The name proposed for this hybrid is for Mr. George Mahon Merrill, collector of the type, in recognition of his valuable work in collecting and making known the plants of southern Oklahoma and of other sections.

× **Quercus stelloides**, *hyb. nov.* (*Q. prinoides* × *Q. stellata*). *Frutex plerumque 1–2 m. altus: folia obovata, inciso-lobata, lobis ovatis utrinque 4–6 vel lobis medii paris oblongis subtruncatis, supra viridia, leviter pubescentia vel matura glabra, infra pallida, subtiliter denseque stellato-pubescentia.*

MISSOURI: Greenwood, Jackson Co., *B. F. Bush*, nos. 10227 and 10227A, Oct. 3, 1923, no. 10330, Sept. 5, 1924; same locality, *E. J. Palmer*, no. 26032, Sept. 5, 1924. KANSAS: Neodesha, Wilson Co., *E. J. Palmer*, 21398, May 23, 1922, 22007 (type), Sept. 18, 1922, 24372, Oct. 31, 1923. OKLAHOMA: Muskogee, *E. J. Palmer*, no. 14285, June 30, 1918. All specimens in the herbarium of the Arnold Arboretum.

The post oak (*Quercus stellata*) is widely distributed in the southern

¹See Palmer, E. J., Notes on some plants of Oklahoma (*Jour. Arnold Arb.* 15: 127–134. 1934).

United States south of a line from Cape Cod to southern Iowa, Kansas, and central Texas. The shrubby chestnut oak (*Quercus prinoides*), sometimes called chinquapin oak in the eastern states and shin oak throughout most of its range, occupies a belt mainly north of the range of the post oak. However, the ranges of the two species overlap widely, and in the region where they are found growing together hybrids have been observed and collected in several places. The hybrid can usually be recognized readily by the intermediate character of the leaves, which differ widely in the two parent species, both in shape and in the character of pubescence.

× ***Quercus humidicola***, hyb. nov. (*Q. bicolor* × *Q. lyrata*). *Hybrida intermedia inter parentes; arbor ad 15–20 m. alta; folia eis parentum similia et intermedia, subtus pallida, pubescentia.*

MISSOURI: low woods, Campbell, *B. F. Bush*, no. 6365 (type), Oct. 6, 1910. ILLINOIS: low woods near Mounds, Pulaski Co., *E. J. Palmer*, nos. 16634 and 16642, Oct. 1, 1919; same locality and collector, nos. 19546, 19549, and 19550, Oct. 16, 1920.

The swamp white oak and the overcup oak grow in quite similar situations and are often found together throughout much of their range, and it is, therefore, not surprising that the two species should hybridize.

A specimen collected by Mr. B. F. Bush, near Campbell, Dunklin County, Missouri, is the best example that I have seen of this hybrid, and it may be taken as the type. Collections made by the writer near Mounds, Pulaski County, Illinois, where several specimens were found growing with the supposed parents, appear also to represent this hybrid. The leaves of the type specimen closely resemble in outline those of *Quercus lyrata*, but they are covered on the pale under surface with a close downy pubescence, as in *Q. bicolor*. The acorns of the type are 2.5–2.8 cm. long, 2–2.2 cm. thick, and are borne on peduncles about 3 cm. long. The oblong-ovoid nuts, resembling those of *Q. bicolor* in shape, though somewhat larger than is usual in that species, are one half or less enclosed in the comparatively shallow cups, the lower scales of which are thickened and corky, as in *Quercus lyrata*. The leaves and fruit on some of the other specimens vary in different degrees between those of the two parent species. In the absence of fruit the hybrid may usually be identified by the close velvety pubescence on the under surface of the leaves, which may otherwise resemble those of the overcup oak.

HERBARIUM, ARNOLD ARBORETUM,
HARVARD UNIVERSITY.

CHRYSOMYXA EMPETRI — A SPRUCE-INFECTING RUST

J. H. FAULL

With one text figure and plates 202, 203

Chrysomyxa Empetri (Persoon) Schroeter has been known for considerably more than a century, but only on *Empetrum* and almost solely with respect to its uredo-stage. DeCandolle (5) described its uredia in 1815 from specimens distributed two years earlier in Mougeot and Nestler's *Stirpes Cryptogamae Vogeso-Rhenanae* and to which Persoon had attached the name *Uredo Empetri*. Link (10), Wallroth (14) and Karsten (8) in turn, and in each instance on wholly untenable grounds, transferred it to the genera *Caeoma*, *Erysibe* and *Thecopsora*, respectively. Schroeter (12), basing judgment on the uredia, just as did the others but with happier discrimination, placed it in the genus *Chrysomyxa*. The following year (1888) and apparently independently, Rostrop (11) also referred it to *Chrysomyxa*; but he did so with a probably better reason because he stated he had found the telia on *Empetrum nigrum* in Greenland. Rostrup did not describe the telia and what became of the collections he may have made is not known. That both Schroeter and Rostrup were right, however, was recently substantiated by Jørstad (7) who described the telia in 1935 from specimens long preserved in the Botanisk Museum, Oslo — specimens which had been collected by Axel Blytt, July 1887, at Sør-Trøndelag, Kongsvoll in Opdal, Norway. Through the courtesy of Professor Jørstad I have had the opportunity of examining this material. Unquestionably the rust is a *Chrysomyxa*.

Collections of *Chrysomyxa Empetri* on *Empetrum nigrum* have been made in most of the major areas of distribution of *E. nigrum* (6) and recently Arvidsson (3, 4) has reported it on a collection of *E. rubrum* in the Gray Herbarium of Harvard University — a collection made some years ago by W. S. Brooks in the Falkland Islands. Indeed, it occurs so frequently in both mycological and phanerogamic herbaria that it can properly be classed as a very common, widely-distributed rust. Except, however, as noted above, the uredo-stage only has been recognized. Scant as have been the findings of the telial stage, for the haploid phase there have been no claims at all. If collections have been made, they have been referred to other species. Of course it is generally assumed that there is or has been a haploid phase and that it probably would be

on an alternate host. But the assumption has rested wholly on analogy, because there has been an entire absence of concrete evidence. Fortunately that evidence is now in hand and at last it is possible to present a complete account of this interesting rust and to offer explanations of the apparent rarity of its critical telial stage and the failure to recognize its haploid phase.

Thus far the telia of *Chrysomyxa Empetri* appear to have been found but three times — (a) by E. Rostrup (11) in Greenland, (b) by G. Lagerheim (9) near Tromsö, Norway, (c) by Axel Blytt (Jørstad 7) in Norway. So, regarding the occurrence of the telial stage, Sydow (13) expresses an opinion from which there has been so far no dissent, namely, "Diese wird jedenfalls nur sehr selten ausgebildet." The correctness of that opinion is now open to question in view of the fact that in June 1935, at about the time spruce buds were breaking, I discovered telia on *Empetrum nigrum* in great abundance at two stations, about 70 miles apart, on the south shore of the River St. Lawrence in the Province of Quebec — near Metis and Trois Pistoles, respectively. Revisiting these stations in June 1936 I found an equally heavy crop. Always they were the first sori to mature and only towards the end of their functional period did uredia begin to appear in large numbers. They remained active about two weeks, at the end of which time the leaves bearing them rapidly withered and their sori became no longer recognizable. It is also significant that the cultures recorded in Table 2, below, manifested the same phenomena. Judging, therefore, from these experiences, it is quite possible that telia are not rare and that they would be located in many places if the search were properly timed. They should be looked for on overwintered foliage during a brief period in the spring or early summer, according to the climate of the respective localities. To these records I would add my discovery of telia in a collection made by Professor Roland Thaxter on Mt. Washington, N. H., July 3–9, 1886 (*Reliquiae Farlowianae*, no. 691).

My research interest in *Chrysomyxa Empetri* was actually first aroused by the chance finding, on August 25, 1933, a profuse display of an unknown, orange-colored *Peridermium* on *Picea glauca* at Metis Beach, Quebec. *Empetrum nigrum*, rusted with *C. Empetri* in its uredo-stage, formed a carpet under the affected spruces. This association and the absence of other *Chrysomyxa*-susceptible hosts suggested that the unknown *Peridermium* belonged to the hitherto unrecognized haploid phase of *C. Empetri*. If this were true then there must have been a crop of telia on the associated *Empetrum*. I returned to the same spot on

June 30, 1934, but found that the new foliage of the spruces was already showing severe infection; the telial stage, on *Empetrum*, if there had been one, was past, leaving few tangible remains. The most that I could discover of telia, were what appeared to be exhausted sori on browned, withered leaves. The next year I arrived three weeks earlier and at an especially opportune date because the first telia to mature were just being exposed through the rupture of epidermis overlaying them. The abundance of telia was so great that upturned shoots of *Empetrum* appeared as though liberally sprinkled with miniature, yellow cushions. Yet at the end of another two weeks the telia were exhausted and for the main part had disappeared. With so much telial material available, culture experiments were at once initiated.

These experiments have comprised a total of 38 culture tests, as follows — A. From *Empetrum nigrum* to *Picea*: (1) 22 tests on *Picea glauca* in 1935; (2) 6 tests on *Picea glauca* in 1936; (3) 2 tests on *Picea rubens* in 1935. B. From *Picea glauca* to *Empetrum nigrum*: (4) 8 tests in 1935–6.

The results of the experiments listed under "A" above are recorded in Table 1. The tests were made on vigorous young trees 8 to 25 feet in height, located on the margin of pasture lands at "Green Gables," Leggatt's Point, Quebec, five miles distant from the source of the inoculum. *Empetrum nigrum* and *Chrysomyxa* rusts of all kinds were absent from the immediate neighborhood. The experiments were protected in part by screens during the period of incubation. All of the cultures were highly successful, as is shown by a photographic reproduction of one of them in plate 202. The rest of the foliage of the experimental and adjacent spruces remained entirely free from infection.

The results of the experiments listed under "B" above are recorded in Table 2. The cultures were made at the Arnold Arboretum, Harvard University, on a vigorous mat of *Empetrum nigrum* growing in partial shade between two greenhouses — the only examples of living *Empetrum* in the Arnold Arboretum. This mat of *Empetrum* originated from seed sent from Kew Gardens, England and planted in 1930 by Mr. William H. Judd, Propagator at the Arnold Arboretum, under no. 727–30. Eight shoots of the mat were inoculated — (a) 4 with aeciospores collected from natural infections at Metis Beach, Quebec and (b) 4 with aeciospores collected from my cultures on *Picea glauca* at Leggatt's Point, Quebec, in 1935. Seven of these experiments gave positive results, the infections producing a few uredia and many telia. No rust appeared elsewhere on the mat.

TABLE 1

CHRYSOMYXA EMPETRI FROM EMPETRUM NIGRUM TO PICEA,
USING FIELD-COLLECTED TELIAL INOCULUM(a) Experiments 1-5, 7-12; on *Picea glauca*.

Inoculations made June 15, 1935 on new shoots of spruce partly expanded.

Spermogonia first observed June 28, 1935.

Peridermia appeared early in August.

Materials were harvested August 24, 1935.

Heavy infection in all experiments, and on needles of current season only. Thus in no. 4 nearly all of the approximately 500 needles of the current season inclosed in the inoculation tube became infected and produced peridermia.

Controls remained free from infection.

Specimens preserved in Herb. J. H. Faull under no. 12,702 (1-5, 7-12).

(b) Experiments 13-24; on *Picea glauca*.

Inoculations made June 20, 1935 on new shoots of spruce partly expanded.

Peridermia appeared early in August.

Materials were harvested August 24, 1935.

Heavy infection in all experiments, and on needles of current season only.

Controls remained free from infection.

Specimens preserved under no. 12,703 (13-24).

(c) Experiments 25-29; on *Picea glauca*.

Inoculations made June 21, 1936 on new shoots of spruce quite fully expanded.

Peridermia appeared about August 1, 1936.

Materials were harvested August 9, 1936.

All experiments showed infection though not nearly so abundant as in the experiments of 1935. The youngest needles only of the current season became infected.

Controls remained free from infection.

Specimens preserved under no. 12,877 (25-29).

(d) Experiment 6; on *Picea rubens*.

Inoculation made June 15, 1935 on new shoots of spruce partly expanded.

Spermogonia first observed June 28, 1935.

Peridermia appeared early in August.

Material was harvested August 24, 1935.

Heavy infection.

Controls remained free from infection.

Specimens preserved under no. 12,702 (6).

(e) Experiment 30; on *Picea rubens*.

Inoculation made June 21, 1936 on new shoots of spruce quite fully expanded.

Peridermia appeared about August 1, 1936.

Material was harvested August 9, 1936.

Rather light infection and on youngest needles only of current season.

Controls remained free from infection.

Specimens preserved under no. 12,877 (30).

TABLE 2

CHRYSOMYXA EMPETRI FROM PICEA GLAUCA TO EMPETRUM NIGRUM, USING FIELD-COLLECTED AECIOSPORES IN EXPERIMENTS 1-4, AND CULTURE-PRODUCED AECIOSPORES IN EXPERIMENTS 5-8, FROM EXPERIMENTS RECORDED UNDER (A) AND (B), TABLE 1. (1, 2, 3)

No.	Date of inoculation	First appearance of sori	Kinds of sori	No. of needles infected	Date harvested
1	3.IX.35	{ 28.XI.35 30.IV.36	II III	1 1	30.IV.36 7. V.36
2	3.IX.35	No infection			
3	3.IX.35	30.IV.36	III	4	13. V.36
4	3.IX.35	30.IV.36	III	4	5. V.36
5	3.IX.35	30.IV.36	III	15	13. V.36
6	3.IX.35	30.IV.36	II, III ⁴	18	11. V.36
7	3.IX.35	{ X.35 30.IV.36	II II, III ⁵	6 11	28. V.36 5. V.36
8	3.IX.35	{ X.35 30.IV.36	II III	1 7	13. V.36 13. V.36

(1) All controls remained free from infection.

(2) These experiments were conducted at the Arnold Arboretum, Harvard University, Jamaica Plain, Mass.

(3) The aeciospores used as inoculum were obtained at Metis Beach, Quebec.

(4) Four uredia and 50 telia.

(5) One uredium, 18 telia, 10 sori undetermined.

Chrysomyxa Empetri (Pers.) Schroeter in Kryptog. Flora Schles.
3¹: 372 (1887). (II). O, I, II, III.

Uredo Empetri Pers. (in litt.) in Moug. and Nestl. Stirp. Crypt.
Vogeso-Rhen. no. 391. (1813). No description.

Uredo Empetri Pers. ex DC. in Fl. Fr. 6: 87 (1815).

Cacoema Empetri (Pers.) Link in Willd. Sp. Pl. 6²: 16 (1825).

Erysibe Empetri (Pers.) Wallr. in Fl. Crypt. Germ. 2: 199 (1833).

Thecopsora Empetri (Pers.) Karst. in Bidr. Finlands Nat. Folk, 31:
143 (1879).

Chrysomyxa Empetri (Pers.) Rostr. in Meddel. om Grönland,
Kjöbenhavn, 3: 536 (1888).

Melampsoropsis Empetri (Pers.) Arthur in Résult. Sci. Congr. Bot.
Vienne, p. 338 (1906).

O. Spermatogonia on needles of current season, amphigenous, uniseriate, conspicuous, yellowish, then reddish-brown, slightly elevated, paraphysate, immersed, subepidermal, 135-162 μ broad and 108-135 μ deep, averaging 145 \times 125 μ ; spermatophores unbranched; living spermatia

subglobular to ellipsoid, $5.0-7.0 \times 5.5-10.0 \mu$; extruded in colorless, sticky liquid.

I. Aecia (peridermia) on needles of current season, yellow, amphigenous, uniseriate, on pale yellowish-discolored portions of affected needles, elliptical to subcircular in transverse section, 0.5–1.5 mm. in greatest width and 0.5–2.0 mm. high; peridium colorless, rupturing at the apex; peridial cells polygonal, elongate vertically, not imbricate or but slightly so, in a single layer, $19-54 \times 32-76 \mu$, with outer walls smooth, about 1μ thick, and inner walls rather coarsely verrucose, $4-6 \mu$ thick; aeciospores yellow, ellipsoid or ovoid, rarely subspherical, $22-32 \times 27-54 \mu$, averaging about $27 \times 42 \mu$; walls of aeciospores closely and rather coarsely verrucose, the warts more or less dehiscent at maturity, hyaline and $1.5-2.0 \mu$ thick.

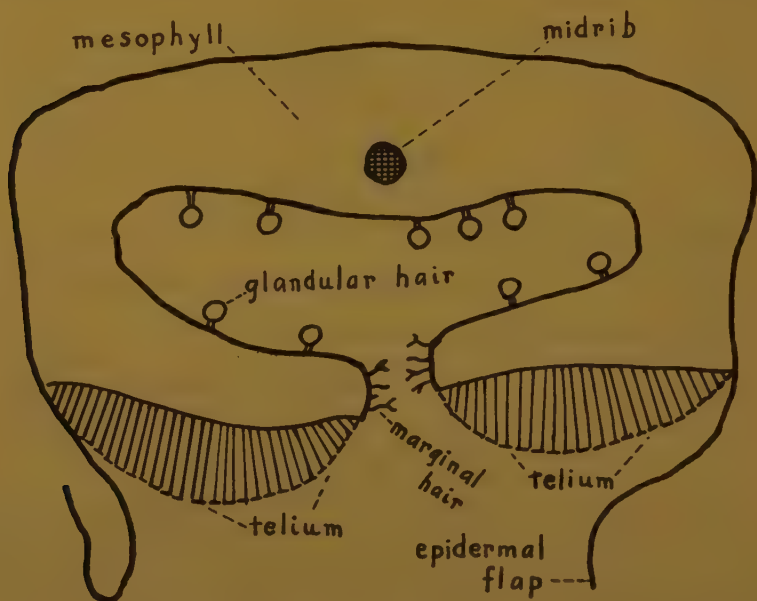


FIGURE 1. Schematic drawing of transverse section of a leaf of *Empetrum nigrum* with two mature telia of *Chrysomyxa Empetri*. Note ruptured epidermis over each telium. Drawn to scale. $\times 100$.

II. Uredia epiphyllous, one to few on a leaf, pustular, convex before rupture, becoming concave as spores are discharged, subepidermal, round or elliptical to linear, 0.2–2.0 mm. in major axis; peridium distinct, adherent to overlying epidermis which ruptures widely at maturity, $15-17 \mu$ thick; peridial cells in a single layer, angular, thin-walled, $10-20$

μ in diameter; urediospores orange, catenulate, with intercalary cells, pulverulent, ellipsoid, ovoid or subglobose, $21-27 \times 27-48 \mu$, averaging about $25 \times 35 \mu$; walls of spores hyaline, closely and rather coarsely verrucose, $1.5-2.0 \mu$ thick.

III. Telia in spring or early summer on overwintered leaves, epiphyllous, one or two to few on a leaf, yellow, cushion-shaped, waxy, subepidermal, overlying epidermis widely rupturing at maturity, exposed surface yellow to straw-colored, relatively smooth, compact and fine-textured, subcircular to mostly much elongate, often nearly as long as the leaf itself, $0.5-3.0$ mm. in major axis; no peridium; teliospores with yellow contents, catenulate, 3 to 6 in a chain, without intercalary cells, smooth, thin-walled, $18-21 \times 19-24 \mu$. The teliospores germinate promptly *in situ* at maturity, beginning with those that are terminal and the basidia soon form a dense velvety nap. Basidia pale yellow, slightly curved to strongly arched, typically 4-celled, $7-8 \mu$ in diameter and up to 65μ in length. Basidiospores with yellow contents, very thin-walled, subglobose to slightly ellipsoid, varying from $10-15 \mu$ in diameter but usually about 12μ .

HOSTS AND DISTRIBUTION

O, I. *Picea glauca* (Moench) Voss* in Quebec (nature and cultures).
Picea rubens Sarg.* in Quebec (cultures).

II. *Empetrum nigrum* L. in United States (Me., N. H., Vt.*, N. Y.), Alaska*, Canada (B. C., Alta.*, Que., N. S.*), Newfoundland*, Greenland, Latvia, Norway, Sweden, Denmark, Great Britain, France, Germany, Austria, Czechoslovakia, Hungary, Switzerland, Poland, Finland, Russia (in Europe), Siberia, Japan.

Empetrum atropurpureum Fern. & Wieg.* in Quebec.

Empetrum Eamesii Fern. and Wieg.* in Newfoundland.

Empetrum rubrum Vahl in Falkland Islands.

III. *Empetrum nigrum* L. in Greenland, Norway, Quebec*, New Hampshire*.

TYPE LOCALITY.

Vosges, France; uredia on *Empetrum nigrum*. (Moug. and Nestl., *Stirpes Cryptogamae Vogeso-Rhenanae*, no. 391. 1813.)

ILLUSTRATIONS.

Grove in British Rust Fungi, p. 311, fig. 235; Arthur in Manual of the Rusts in United States and Canada, p. 31, fig. 41.

*New records.

EXSICCATI

Moug. and Nestl. Stirp. crypt. vogeso-rhen. 391; Fuckel Fg. rhen. 2697; Sydow Myc. germ. 971; Sydow Ured. 143, 2394; Thuemen Myc. univ. 1044; Racib. Myc. polon. 149; Smarods Fg. latvici 70; Eriksson Fg. par. scand. 177; Linhart Fg. hung. 342; Reliq. Farl. 691.

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EXPLANATION OF PLATES

PLATE 202

Chrysomyxa Empetri (Pers.) Schroet. Inoculation experiment No. 17 of 1935. *Picea glauca* (Moench) Voss inoculated with telial material from *Empetrum nigrum* L. collected June 20, 1935. Date of inoculation June 20; harvested August 24, 1935. × 1. Herbarium J. H. Faull no. 12,703 (17).

PLATE 203

Chrysomyxa Empetri on *Picea glauca*. Natural infection. Metis Beach, Quebec. August 25, 1935. × 1. The leafless internodes of 1934 indicate a very heavy rust infection in 1934. Herbarium J. H. Faull no. 12,704.

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CHRYSOMIXA EMPETRI—A SPRUCE INFECTING RUST



CHRYSOMIXA EMPETRI—A SPRUCE INFECTING RUST

CONTROL OF THE GYMNOSPORANGIUM RUSTS BY MEANS OF SULPHUR SPRAYS

J. D. MACLACHLAN AND IVAN H. CROWELL

With plate 204

INTRODUCTION

CROWELL (1934, 1935) has already demonstrated the value of a colloidal sulphur as a means of controlling *Gymnosporangium Juniperi-virginianae* Schw. on ornamental apple trees, and *G. clavipes* C. and P. on *Juniperus virginiana* L. and *Amelanchier oblongifolia* (T. and G.) Roem. Both of the writers of this paper, individually and jointly, have been studying and experimenting with sulphur sprays for several years in relation to their effectiveness as a means of controlling Gymnosporangium rusts. The results obtained are presented here, along with recommended spray schedules for the control of *G. Juniperi-virginianae*, *G. globosum* and *G. clavipes* on their respective alternate hosts.

SULPHUR SPRAYS WITH RELATION TO TOXICITY TO GYMNOSPORANGIUM SPORES

A. THE TOXIC EFFECT ON THE BASIDIOSPORE

Apparently sulphur, in contact with the basidiospores of the Gymnosporangium rusts, has little toxic effect on these spores prior to their being moistened and permitted to germinate. Moreover, the germinating spores must be in close proximity to the sulphur particles to be materially affected. These phenomena were illustrated by a simple experiment. A small amount of linseed oil was mixed with "Flotation sulphur," made up at six pounds to one hundred gallons of water. The mixture was sprayed on a glass slide and allowed to dry. Fresh basidiospores of *G. Juniperi-virginianae* were obtained from germinating teliospores and permitted to fall on the prepared slide. After the spores had been in contact with the sulphur for a period of ten hours, the slide was lightly atomized with distilled water and inverted in a moist chamber. Due to the presence of the oil, the water formed in small droplets carrying some of the spores to the exposed surfaces of the droplets while the remainder of the spores remained in contact with the sulphur. Twelve hours after atomizing, no germ tubes were evident on the spores which remained in contact

with the sulphur either within a droplet or at its periphery but more than seventy per cent of the spores on the exposed surfaces of the droplets and free from the sulphur exhibited normal germ tubes. This experiment indicates (1) that the sulphur has little effect on the spores until they begin to germinate and (2) that the sulphur particles must be in close proximity to the germinating spores to have a toxic effect.

B. SIZE OF SULPHUR PARTICLE WITH RELATION TO TOXICITY

It is the belief of Wilcoxon and McCallan (1931) that particle size rather than concentration is the chief factor that determines the relative efficiency of sulphur sprays; the toxic value of the sulphur varies inversely with the diameter of the particle. From this it would appear that a colloidal type of sulphur would be the most efficient. On the other hand, sulphur volatilizes when exposed in a thin layer to wind and direct sunlight, the rate of volatilization varying directly with the size of the sulphur particle. These two factors would indicate that an efficient sulphur should contain particles of active ingredients whose sizes varied from colloidal to a size that would not be completely volatilized by the time of the next spray application.

C. PARTICLE SIZE OF THE INGREDIENTS OF CERTAIN SULPHURS

The relative particle sizes of the ingredients of eight sulphur sprays were illustrated by means of photomicrographs. The sulphurs selected were Dry Lime, Flotation, Kolofog, Linco Colloidal, Liquid Lime, Magnetic Wettable, the Nova Scotia formula and Sublimated sulphur. The respective sulphurs were made up according to the schedule given in Table I. No spreader or sticker was added. Samples of the respective sulphurs were taken immediately after their preparation and sprayed by means of atomizers on glass slides and allowed to dry. Microscopic examination revealed in all cases that the spray ingredients were quite uniformly distributed over the surfaces of the prepared slides. Thus it made little difference what portion of a slide was photographed. Photomicrographs were made as silhouettes at a magnification of 545 diameters and are illustrated in Plate 204. (For further details see explanation of plate.) These photomicrographs might well represent the optimum distribution of the particles of the respective sulphurs on the surface of sprayed foliage. Within Plate 204 are shown photographs of basidiospores and aeciospores of *G. globosum*, also at a magnification of 545 diameters. One can visualize from Plate 204 how it might be possible for a basidiospore to germinate and penetrate the surface of a leaf and yet not come in contact with a particle of one of the coarser sulphurs.

TABLE I

THE SULPHUR SPRAYS, TOGETHER WITH THEIR CONCENTRATIONS,
USED IN THE INVESTIGATIONS PRESENTED IN THIS PAPER

Sulphurs:

Dry Lime.....	} 6 lbs. to 100 gallons of water.
Flotation.....	
Kolofog.....	
Linco Colloidal.....	
Magnetic Wettable.....	
Sublimated.....	} 1 gallon to 50 gallons of water.
Liquid Lime.....	
Nova Scotia formula.....	Aluminum sulphate4.2 lbs.
	Liquid Lime Sulphur1.4 lbs.
	Calcium arsenate1.2 lbs.
	Water48 gallons

Stickers and spreaders:

- (1) "S. S. S." Sticker and Spreader, produced by the Mechling Chemical Co., Canton, New Jersey. This product contains no lime, is not designated to wet sulphur and can be used with any spray except oil. It was used in the proportion of 3 lbs. to 100 gallons of spray.
 - (2) Fish oil in the proportion of 1 pint to 50 gallons of spray together with dried milk in the proportion of $\frac{1}{2}$ lb. to 50 gallons of spray.
-

D. DURATION OF TOXICITY OF SULPHUR ON SPRAYED FOLIAGE

An attempt was made to determine how long different types of sulphur sprays would protect the foliage from infection by the basidiospores. The sprays selected were Magnetic Wettable, Kolofog, Flotation and Linco Colloidal. The tree selected for experimentation was *Crataegus Jonesae* Sarg., a hawthorn that is very susceptible to *G. globosum*. Separate large branches of the hawthorn were sprayed with the respective sulphurs made up according to the schedule given in Table I. No spreader or sticker was added. Samples of the sprayed branches were inoculated with germinating teliospores of *G. globosum* (1) immediately after the sprays were dry, (2) three days later, (3) five days later, and (4) twelve days later. The experiment was carried out in duplicate, each inoculation on a separate twig. Parallel series of check inoculations were made on unsprayed branches of the same tree. Table II presents data on the results obtained and the following conclusions can be made. (1) The host tree was highly susceptible during the period of experimentation as indicated by the check inoculations. (2) The Flotation and Linco Colloidal sulphurs gave perfect protection for at least five days time but gave practically no protection twelve days

after spray application. A somewhat similar series of experiments (Crowell, 1934) also indicates that Linco Colloidal will not protect the foliage of ornamental apples from infection by *G. Juniperi-virginianae* for a period of more than nine to ten days.

TABLE II
DURATION OF TOXICITY OF FOUR SULPHUR SPRAYS TO
BASIDIOSPORES OF *G. GLOBOSUM* WHEN APPLIED TO
HAWTHORN FOLIAGE

Spray	Degree of infection from successive inoculations obtained			
	Immediately after spraying	3 days later	5 days later	12 days later
Magnetic Wettable	2	1	2	2
Kolofog	1	3	2	2
Flotation	0	0	0	2
Linco Colloidal	0	0	0	3
Check (unsprayed)	3	3	3	3

Experiment begun May 19, 1933.

The degrees of infection obtained by the inoculations were graded as 0, 1, 2 and 3 where 0 — no infection obtained

1 — 1-5 lesions per leaf

2 — 5-20 lesions per leaf

3 — more than 20 lesions per leaf.

III. FIELD TESTS USING FOUR DIFFERENT SULPHURS TO CONTROL *G. JUNIPERI-VIRGINIANAE*

In view of the foregoing investigations, four sulphurs, namely, Flotation, Linco Colloidal, Liquid Lime and the Nova Scotia formula were selected for field tests. These sulphurs were used as a means to control *G. Juniperi-virginianae* on susceptible apple trees and on red cedars.

A. CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON APPLES

A number of Wealthy apple trees were marked in a commercial orchard at Wayland, Massachusetts, in August, 1934. These marked trees exhibited severe infection by *G. Juniperi-virginianae* and were used for both spray tests and check purposes the following spring. Spraying was begun on May 2, 1935. The four sulphurs were made up according to schedule with the "S. S. S." sticker and spreader added. (See Table I.) Two trees were used for each spray test; the remaining ones served for check purposes. The spray was applied by means of a hand-pump sprayer. The dates of spray application, as well as conditions of the foliage and the weather conditions at the time of spraying, may be found in Table III.

TABLE III

SPRAY SCHEDULE ON APPLES WITH REFERENCE TO CONDITION OF FOLIAGE AND WEATHER AT THE TIME OF SPRAYING

Date	Foliar condition	Weather
May 2	Leaves $\frac{1}{4}$ - $\frac{1}{2}$ in. long. Flower buds just beginning to show pink tips.	Cool, cloudy.
May 8	Late prepink stage. Leaves expanding.	Cool, cloudy.
May 16	Blossoms opening. Leaves well expanded. A slight frost injury evident.	Clear, warm.
May 23	Petals dropping.	{ Cool, cloudy. No rain since last spraying.
June 3	Many large secondary leaves.	
June 14	No evidence of any infection.	Warm, cloudy.
		Warm, clear.

Note: On May 23, lead arsenate (2 lbs. per 100 gallons) was added to the respective sprays to protect the foliage from insect injury. In early June, the owner of the property sprayed the trees with lead arsenate and dry lime sulphur but, as evidenced by the check trees, this spraying did not affect the results of the experiment.

Records on the results of the experiment were collected on August 9, 1935. The degree of control was based on the reduction in the number of foliar lesions on sample branches removed at random from various portions of the sprayed and checked trees. In Table IV may be found data on the results obtained.

As may be seen from Table IV, better than ninety per cent control of the rust was obtained. It may be noted that the experiment with the Nova Scotia formula in which one spray was omitted (See explanation under Table IV) apparently gave the best results of all. This indicates that the differences recorded for the sulphurs, with the possible exception of Flotation, are of no significance as to their relative value. If of any significance they indicate differences in thoroughness of spraying. It must be remembered that the spraying was done with a hand-pump sprayer.

B. CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON RED CEDARS

In Massachusetts, the aeciospores of *G. Juniperi-virginianae* are dispersed from about the middle of July until the leaves drop in the autumn. This factor necessitates protection to the red cedar for a much longer period than is necessary for the apple. A spray program was carried out in 1934 which involved various time intervals for spray application and

extended from the time of the initial discharge of the aeciospores until December.

A large nursery at Framingham, Massachusetts, afforded an excellent opportunity for experimentation. A plantation of approximately five hundred large red cedars, arranged in five rows, runs parallel to, and about one hundred yards from, a row of *Malus ioensis plena* Rehd. Both hosts had exhibited very heavy infection by *G. Juniperi-virginianae* for at least two years prior to the initiation of the spray program.

The sprays were made up according to the schedule given in Table I. As a sticker and spreader, the fish oil and dried milk were added. For experimentation, trees were selected which exhibited an abundance of old galls of *G. Juniperi-virginianae*. Parallel spray programs were carried out for each of the four sulphurs. Eight trees, for each sulphur, were sprayed just prior to the initial discharge of the aeciospores, namely, July 25, 1934. Subsequent spray applications were made to respective pairs of these trees at time intervals of one, two, three and four weeks. Spraying was discontinued on one tree of each pair on October 31 by which time practically all the aeciospores had been dispersed. The last spray was applied on December 5. The remainder of the plantation served for check purposes.

TABLE IV
DATA ON FUNGICIDAL CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON
THE WEALTHY APPLE

Sulphur spray	Total leaves examined	Number of infected leaves	Total number of lesions	Number of lesions per leaf of total foliage examined	Reduction of rust on total foliage examined
Check (unsprayed)	723	223 (30.8%)	2214	3.06	—
Flotation	1109	152 (13.7%)	409	0.37	88%
Linco	998	79 (7.9%)	226	0.23	93%
Liquid Lime	760	33 (4.3%)	99	0.13	96%
Nova Scotia	569	43 (7.6%)	104	0.18	94%
Nova Scotia (less 1 spray)	511	22 (4.3%)	39	0.08	97%

Note: The data for the two trees sprayed with the Nova Scotia formula have been kept separate. Through error one tree was not sprayed on May 16. However, no rains had occurred, sufficient for basidiospore dispersal, between May 16 and the following spray application. Consequently, the omission of this spray should make no difference in the results obtained.

Records of the control obtained by this series of spray programs were collected in May 1936, following a rainy period when the galls had gelatinized and could be counted easily. Counts were made of the number of galls on each of the sprayed trees and on four unsprayed trees selected at random. In Table V may be found data on the results obtained. A comparison of the number of galls on sprayed and on unsprayed trees revealed better than ninety per cent control. This degree of control is evident throughout the entire series of spray programs. Any differences in the degree of control obtained cannot be attributed to either the particular sulphur used or the time interval of spray application. Moreover, the spray schedule which extended from the time of the initial discharge of aeciospores until the last of October gave as good control as the schedule which continued until the first of December. Such variations as do occur in the degree of control obtained may be attributed to differences in thoroughness of spraying. As in the spray experiments on the apple trees, the sulphurs were applied by means of a hand-pump sprayer.

RECORDS OF THE CONTROL OBTAINED IN COMMERCIAL AND ORNAMENTAL PLANTINGS BY MEANS OF A COLLOIDAL SULPHUR

During the past five years extensive spray programs have been conducted, using a colloidal sulphur, for the control of the Gymnosporangium rusts on their respective alternate hosts. The spraying was done on commercial and ornamental plantings in the vicinity of Boston, Massachusetts. In all cases Linco Colloidal sulphur was used in the proportion of 6 lbs. to 100 gallons of water. The "S. S. S." sticker and spreader (See Table I) was added in the proportion of 2 lbs. to 100 gallons of spray. Most of the spraying was done with a power sprayer.

In certain instances trees were left unsprayed and served as checks to indicate the degree of control obtained. Some of these instances are now recorded to illustrate the effectiveness of using a sulphur fungicide to control the Gymnosporangium rusts.

A. CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON APPLES

The Apple Scab Schedule as recommended by the Massachusetts State Agricultural Experiment Station was followed while spraying a number of orchards. McIntosh, Wealthy and Ben Davis apples predominated in these orchards. During the latter part of the season, counts were made of the number of foliar lesions on approximately five hundred leaves taken as random samples from various sprayed branches in each

TABLE V
DATA ON FUNGICIDAL CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON THE RED CEDAR

SULPHUR SPRAY		TIME INTERVALS OF SPRAY APPLICATION											
		One week				Two weeks				Three weeks			
		Series A*		Series B		Series A		Series B		Series A		Series B	
		No. galls	Control %	No. galls	Control %	No. galls	Control %	No. galls	Control %	No. galls	Control %	No. galls	Control %
Flotation		0	100	3	98	4	98	0	100	1	99	2	99
Linco		3	98	—**	—	9	95	1	99	6	97	7	96
Liquid Lime		1	99	1	99	1	99	1	99	2	99	0	100
Nova Scotia		0	100	0	100	2	99	1	99	0	100	2	99
The number of galls on four unsprayed trees was 90; 139; 240; 300, respectively.													

By control is meant the percentage reduction in the number of galls on the sprayed trees as compared with the number on the unsprayed trees.

*The A series of trees were sprayed from July 25 to October 31; the B series from July 25 to December 1, 1934.

**In two cases the trees were removed and data could not be obtained.

of the orchards. Similar samples from adjacent and unsprayed McIntosh trees were also taken and served for check purposes. The results of the counts were indicative of better than ninety-five per cent reduction in the number of foliar lesions. The effect of the control obtained was clearly visible in the much healthier foliage and the production of a better quality and a larger quantity of fruits on the sprayed trees.

B. CONTROL OF *G. JUNIPERI-VIRGINIANAE* ON RED CEDARS

Several groups of red cedars in various localities have been sprayed during the past five years. Prior to this spray program the trees had exhibited severe infection by the rust. For the first two years the spray was applied at monthly intervals during July, August and September. The schedules for the next three years was changed to three sprays at three week intervals beginning early in July. Due to the long time interval for the development of the rust, the results of this spray program are available for the first three years only. An average of one to four galls of the rust per tree was all that could be found and these infections were easily removed by hand picking. Neighboring unsprayed trees continued to exhibit large numbers of the galls.

C. CONTROL OF *G. CLAVIPES* ON POMACEOUS HOSTS

Gymnosporangium clavipes is primarily a fruit parasite on its pomaceous hosts. The period of susceptibility of the fruits is confined to the early stage of their development. Ornamental plantings of *Amelanchier* and *Crataegus* were sprayed for the control of this rust. Three applications gave the best and the most consistent results. The first application was made when the blossom buds were opening. The second and third applications were made at weekly intervals. On species of *Amelanchier*, as high as ninety-eight per cent of the fruits remained free from infection while ninety-five per cent of the fruits on unsprayed nearby plants were infected by the rust. On species of *Crataegus*, a comparison with neighboring unsprayed trees showed a reduction of approximately eighty per cent in the number of infected fruit.

D. CONTROL OF *G. CLAVIPES* ON RED CEDARS AND ON COMMON JUNIPERS (*JUNIPERUS COMMUNIS*)

The number of spray applications to red cedars and common junipers was determined by the length of time over which aeciospores are discharged from diseased fruits of the respective alternate hosts. The period of discharge of aeciospores from diseased *Amelanchier* species normally begins in late May and continues until early July when the fruits drop. On the other hand, diseased fruit of species of *Crataegus*

will remain on the tree until late fall. Moreover, aeciospores have been found on diseased hawthorn fruit throughout the season.

A number of plantings of red cedars and common junipers were sprayed over a period of five years to control *G. clavipes*. These plants had all shown heavy infections by the rust. In one instance the owner had contemplated their complete removal. In localities where diseased Amelanchier species were the source of inoculum, the initial spray application was made the latter part of May. Spraying was continued at three week intervals on the common juniper, and at three to four week intervals on the red cedar, until early in July. New infections were reduced to one to four lesions per sprayed tree and at the end of the five year spray program practically all of the old perennial infections had died. In localities where diseased Crataegus fruits were the source of inoculum, spray applications were made at three week intervals from the time of the initial discharge of the aeciospores, namely, the latter part of May, until the hawthorn fruits had dropped in the fall. A comparison of the number of lesions formed on branches of the sprayed and of neighboring unsprayed trees indicated better than seventy-five per cent control.

RECOMMENDATIONS FOR FUNGICIDAL CONTROL OF THE GYMNOSPORANGIUM RUSTS

A. SELECTION OF FUNGICIDE

The results of the investigations presented in this paper indicate that at least certain of the sulphur fungicides may be used effectively to control the Gymnosporangium rusts on any of their respective alternate hosts. The finer sulphurs proved to be the more efficient. Linco Colloidal, Liquid Lime, the Nova Scotia formula and possibly Flotation (See Table I) gave satisfactory control for the particular rusts against which they were tested. The addition of a sticker and spreader is recommended.

B. DETERMINANT FACTORS IN THE FORMULATION OF THE SPRAY SCHEDULES

The time of year for spray application

The date of initial spraying, as well as the length of time over which spray applications must be made are determined by two factors, (1) the period of time during which the respective hosts are susceptible and (2) the period of time over which the spores are dispersed from diseased alternate hosts. For a large proportion of the pomaceous hosts the period of susceptibility of the foliage is restricted to approximately two

months after the leaves develop (Crowell, 1934) (MacLachlan, 1935a). Certain species of *Malus*, however, have been found to be susceptible to *G. Juniperi-virginianae* throughout the growing season (Crowell, 1934). The fruits of *Amelanchier* and *Crataegus* are resistant to *G. clavipes* one month after the blossoms open (Crowell, 1935). It is possible that *Juniperus* hosts are susceptible to these rusts throughout the period of dispersal of the aeciospores.

The basidiospores of these rusts are the source of infection on the respective pomaceous hosts. These spores are dispersed during or following rainy periods in the spring and are capable of causing infection immediately. Under normal conditions their initial release takes place during the latter part of April which is shortly before the leaves or fruit have appeared on the pomaceous hosts. Depending upon the number of rains, most of the teliospores will have germinated by the middle of June. In some instances ungerminated teliospores of *G. Juniperi-virginianae* have been found on the galls in July. It is doubtful, however, that such spores give rise to a sufficient degree of infection to be worthy of consideration; the foliage and fruit of most of the pomaceous hosts are resistant to infection by this late period.

The aeciospores of these rusts are the source of infection on the *Juniperus* hosts. These spores are dispersed during the summer and, unlike the basidiospores, their dispersal is not dependent upon periods of rainfall. The time of their dispersal varies with the different rusts and in some cases with the pomaceous hosts attacked. The aeciospores of *G. clavipes* are dispersed from diseased *Amelanchier* fruit from late May until the middle of July at which time the infected fruit drop and decay. *Crataegus* fruits, infected by *G. clavipes*, do not drop until autumn and a certain number of aeciospores may be found on these diseased fruits throughout the season. The initial release of the aeciospores of *G. Juniperi-virginianae* takes place early in July; those of *G. globosum* two or three weeks later. Aeciospores of both of the latter rusts may be found on the diseased organs of their respective pomaceous hosts throughout the summer.

The greater proportion of the aeciospores of all the rusts are dispersed within the first few weeks after their formation. A high percentage of the aeciospores of *G. clavipes* will germinate at the time of their release from the aecia. It is possible, then, that the greatest amount of infection of the *Juniperus* hosts by this rust takes place in June. A very low percentage of the aeciospores of *G. Juniperi-virginianae* and *G. globosum* will germinate at the time of their release from the aecia (Crowell, 1934) (MacLachlan, 1936). If, however, the aeciospores of *G. globosum* are

kept for about six weeks at a temperature of 0°C., better than eighty per cent germination may be obtained. It is possible, then, that a large proportion of the *Juniperus* hosts are infected by *G. Juniperi-virginianae* and *G. globosum* at two rather distinct periods: (1) immediately after the aeciospores are released when low percentages of the spores germinate but spores are in great abundance and (2) later in the season by the aeciospores which required a dormant period prior to their germination but remained on the *Juniperus* foliage during this time interval.

The time interval between spray applications

The time interval between spray applications to the broad-leaved hosts is necessarily short. Fine sulphur volatilizes when exposed to wind and sunlight on broad-leaved foliage. Moreover, the leaves of such plants are most susceptible to the *Gymnosporangium* rusts during their period of rapid expansion (MacLachlan, 1935a). This period usually coincides with the time of active dispersal of the basidiospores. Consistent control of the *Gymnosporangium* rusts on their respective pomaceous hosts will not be obtained if the time interval between spray applications exceeds seven to ten days. A number of instances could be cited where control was not obtained although the correct number of spray applications was made. In each case an analysis of the spray schedule showed that a time interval of more than ten days had occurred in one or more instances between consecutive spray applications. Since the basidiospores of these rusts are dispersed during rainy periods, the time intervals between spray applications should be governed somewhat by the weather. The time interval between the formation of the basidiospores and infection of the pomaceous host is usually a matter of hours. Under cool moist conditions, the basidiospores may live for several days but they are subject to desiccation and are readily killed by high temperatures (MacLachlan, 1935b). The optimum time for spray application to the pomaceous host is immediately before a rainy period.

Longer intervals between spray applications may be employed with safety when spraying the *Juniperus* hosts. The germ tubes of the aeciospores can penetrate the leaves of the red cedar on the upper and stomatal surfaces only. The imbricated arrangement of the leaves is such that the sulphur is retained for relatively long periods of time within the axil formed by the upper surface of the leaf and the stem to which the leaf is attached. Examination of sprayed red cedars revealed that particles of the spray ingredient were still present, in the axils formed by the leaves, six months after the last spray application. Satisfactory control of the *Gymnosporangium* rusts may be obtained when the spray is applied at time intervals of three to four weeks.

C. SPRAY SCHEDULES FOR THE CONTROL OF THREE GYMNOSPORANGIUM RUSTS

The spray schedules have been based on the conditions as they exist in Massachusetts with respect to host and fungus.

1. Control of *G. Juniperi-virginianae* and *G. globosum*.

On pomaceous hosts. Six applications at seven to ten day intervals. The first application should be made prior to the first rain after the young leaves emerge from the buds. The apple scab schedule will give satisfactory control under the condition that no time interval between spray applications exceeds seven to ten days. If there are not sufficient rains during May to gelatinize the telia on infected red cedars and thereby cause most of the teliospores to germinate, it may be necessary to add one extra application to the spray schedule.

On Juniperus hosts. Four applications at three to four week intervals. The first application should be made prior to the initial discharge of the aeciospores, namely, about the middle of July for *G. Juniperi-virginianae* and about the first of August for *G. globosum*.

2. Control of *G. clavipes*

On pomaceous hosts. Three applications at seven to ten day intervals. The first application should be made when the blossom buds are opening. The schedule should be arranged to avoid spraying during pollination.

On Juniperus hosts. The first application should be made during the latter part of May and continued at three to four week intervals. If diseased *Amelanchier* species are the source of the aeciospores the final spray may be made early in July. If diseased *Crataegus* species are the source of the aeciospores, spraying should be continued until September.

SUMMARY

A sulphur fungicide, in contact with viable basidiospores of a Gymnosporangium rust, has little effect on these spores prior to their germination. Moreover the sulphur particles must be in close proximity to the germinating basidiospores to have a toxic effect.

An efficient sulphur for the control of the Gymnosporangium rusts should contain particles of active ingredients whose sizes vary from colloidal to a size that would not be completely volatilized by the time of the next spray application.

From an experiment presented in this paper and from previous investi-

gations it has been concluded that the most efficient of the sulphurs tested would not protect the foliage of the pomaceous hosts for a time interval of more than seven to ten days between spray applications.

Field tests for the control of *G. Juniperi-virginianae* on the Wealthy apple and on the red cedar were made. Four different sulphur fungicides were used. Better than ninety per cent control of this rust was obtained on both of the alternate hosts.

Extensive spray programs, using a colloidal sulphur, have been conducted with successful results in commercial and ornamental plantings for the control of three Gymnosporangium rusts.

Spray schedules for the control of *G. Juniperi-virginianae*, *G. globosum*, and *G. clavipes* on their respective alternate hosts are presented.

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EXPLANATION OF PLATE 204

Illustration of the relative particle size of the ingredients of certain sulphurs

The sulphurs were made up according to the schedule given in Table I of the text. No spreader or sticker was added. The respective mixtures were sprayed on glass slides by means of atomizers, allowed to dry, then photographed. The illustrations show the ingredients of the sprays at a



GYMNOSPORANGIUM CONTROL BY SULPHUR SPRAYS

magnification of 545 diameters. The respective sulphurs are indicated as A - Dry Lime, B - Flotation, C - Kolofog, D - Liquid Lime, E - Linco Colloidal, F - Magnetic Wettable, G - The Nova Scotia formula, and H - Sublimated. Magnetic Wettable is approximately 70% bentonite clay. Some of the finer particles of the Linco Colloidal are barely visible in the Figure. Clusters of crystals were visible on the slide that was sprayed with the Nova Scotia formula. One half of one crystal is illustrated. These crystals disappeared on spraying the slide with water. In the center of the Plate are shown photographs of the basidiospores (X) and the aeciospores (Y) of *G. globosum*. These spores are also illustrated at a magnification of 545 diameters.

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STOMATA SIZE AND DISTRIBUTION IN DIPLOID AND POLYPLOID PLANTS

KARL SAX AND HALLY JOLIVETTE SAX

With plate 205

IN BOTH PLANTS and animals the doubling of the chromosome number in a cell usually results in a corresponding increase in the size of the nucleus and cytoplasmic volume (Wilson 1925). The tetraploid races of *Solanum* examined by Winkler not only had larger stomata and pollen grains than those of the diploid, but, in addition, the chloroplasts were correspondingly larger. More recently Karpechenko (1928) found an increase in stomata size as the chromosome number increased in a series of *Raphanus* \times *Brassica* hybrids, although the relationship was not linear. Navashin (1931) also found a rather close correlation between chromatin mass and cell volume in related species and polyploid races of *Crepis*. The relationship between polyploidy and cell size has provided a method for detecting induced tetraploids in *Zea* simply by examining the stomata (Randolph 1932).

In a recent review of autopolyploidy Müntzing (1936) lists fifty-eight cases of polyploidy within species or closely related species. The intraspecific chromosome races are usually differentiated both in morphological and ecological characters. The polyploid forms are generally somewhat larger, more vigorous, tend to be longer-lived, and usually have a different geographical distribution when compared with their diploid ancestors. Although autopolyploidy does not give rise to new species directly, it may be an important factor in the evolution of plant species.

The frequent occurrence of species with diploid and polyploid races, suggests that polyploids may be found in many other supposedly diploid species, as larger numbers of individuals are examined. If the relationship between cell size and chromosome number would permit the use of herbarium material in detecting polyploids, much of the survey work would be simplified. A comparison of diploid and polyploid races is also of considerable interest because the rate of development is decreased in the tetraploid, accompanied by a number of physiological changes.

We have compared the diploid and tetraploid races of *Tradescantia canaliculata* Rafinesque in some detail, and have compared the stomata distribution in diploid and polyploid races or species in both living and herbarium material in other genera. The chromosome races of *T. canali-*

culata were collected by Dr. Edgar Anderson and were grown in adjacent plots in the Arnold Arboretum. The two races are similar in size and are not easily differentiated except by cytological examination. The tetraploid plant of *Secale cereale* L. used in this work was produced from a diploid by subjecting the pre-embryonic cells to extreme temperatures (cf. Dorsey 1936). Stomata counts from living plants in the Arnold Arboretum were from individuals which had been examined cytologically to determine their chromosome numbers.

The volumes of corresponding cells in tetraploid and diploid plants show a high correlation between cell size and chromosome number in *Tradescantia* (Table I). The pollen mother cells and microspores of the tetraploid are about twice as large as those of the diploid. The microspore nucleus at late prophase is also correspondingly larger in the tetraploid. The chloroplasts of the tetraploid are twice as large as those of the diploid,—a relationship also found in *Solanum* species by Winkler.

Needle-shaped spicules are found in the cells of the stem and are obtained in viscous sap exuded from a cut stem. These spicules are much longer in the tetraploid. The stomata of the tetraploid are larger than those of the diploid, and the number per square mm. of leaf surface is closely correlated with chromosome number. This relationship would be expected where cell size is related to chromosome number, because the area of the flattened epidermal cells should be closely correlated with their volume.

TABLE I
COMPARISON OF DIPLOID AND TETRAPLOID
TRADESCANTIA CANALICULATA

	n	Diploid	n	Tetraploid
Volume of PMC in cu. μ — 1st Tel.	25	5,443	25	9,204
Volume of microspore in cu. μ	25	7,620	25	12,217
Volume of microspore nucleus in cu. μ	25	1,150	25	2,342
Volume of chloroplasts in cu. μ	44	76	62	139
Length of spicules from stem — in μ	35	74	28	112
Stomata per sq. mm. of leaf surface (lower)	50	39	50	19
Length of stomata in μ	50	61	50	78
Number of coils in meiotic chromosome	100	5.5	100	4.5
Cytoplasmic streaming — stamen hairs — μ per sec.	25	5.4	27	4.2
Time of most frequent meiotic divisions		A.M.		P.M.
Propagation from stem cuttings		poor		good

There is little difference in the size of diploid and tetraploid plants of *T. canaliculata*, even though the cells of the tetraploid are twice as large. This means that the tetraploid has about half as many cells as the diploid. The tetraploid does not develop more rapidly than the diploid, so that rate of cell division must be much slower in the tetraploid. The differences in rate of cell division provide an opportunity for a study of certain physiological processes.

The chromosomes of somatic cells are in the form of coiled chromonemata at all stages in the cell cycle, and about 20–25 minor coils are found in metaphase chromosomes; but at meiosis a major spiral is superimposed on the minor or somatic spiral. The occurrence of major spirals at meiosis is attributed to the slower development of the meiotic cell (Sax and Sax 1935). The slower development of the tetraploid *Tradescantia* should be reflected in the degree of major coiling of the chromonemata at meiosis. A comparison of the meiotic chromosomes of the diploid and tetraploid races of *T. canaliculata* shows that the number of coils are decreased considerably in the tetraploid meiotic chromosomes (Table I).

The rate of cytoplasmic streaming in the stamen hairs was compared in the diploid and tetraploid plants. Stamen hairs were taken from freshly-opened flowers and mounted in paraffin oil. A long strand of cytoplasm was selected for observation, and the rate of streaming was determined four times for a certain length of the protoplasmic strand under observation in each cell. Two series of observations were made. In the first series, the average rate of streaming in 15 cells of the diploid was 4.2 microns per second, while in 17 cells of the tetraploid, the rate was 3.2 microns per second. A second series of observations, taken a week later, showed an average rate of 7.1 microns for 10 diploid cells and 5.9 microns for 10 tetraploid cells. Although the rate of streaming is dependent upon environmental conditions, the differences observed suggest that there is greater cytoplasmic activity in the cells of the diploid.

Cytological studies of meiotic divisions of diploid *tradescantias* grown in the field and in the greenhouse show that the meiotic metaphase stages are found much more frequently in the morning. Even during the winter months, few division figures are found after 10 A. M. A comparison of diploids and tetraploids grown in the field showed that in the diploids the meiotic divisions occurred most frequently in the morning, while the same stages in the tetraploid were found to be most frequent in the afternoon,—although the time of division in the tetraploid was not so limited as in the diploid.

Müntzing (1936) has shown that the polyploid forms tend to reproduce vegetatively more frequently than the diploids. This difference is found in the diploid and tetraploid forms of *T. canaliculata*. About a dozen stem cuttings were made of each type. The diploid cutting formed few roots, and only a few survived, while most of the tetraploid cuttings produced roots and survived. However, the rooting ability of the tetraploid *T. canaliculata* is not as good as that of the diploid species, *T. paludosa*.

STOMATA COUNTS

The correlation between chromosome number and size and frequency of stomata in *Tradescantia canaliculata*, suggested the possibility that the size or distribution of stomata might be used as an index of polyploidy in certain species of plants. In *Tradescantia* the relation between chromosome number and the distribution of stomata is much more marked than the relation between chromosome number and length of stomata. In Karpechenko's (1928) series of *Raphanus* \times *Brassica* polyploids, the length of the stomata in mm. \times 1350 was about 7 for the diploids and 9.7 for the tetraploid. Stomata counts taken from his illustrations show about 550 per square mm. for the diploid parents, 800 for the diploid F_1 , and 350 for the tetraploid hybrid. There seems to be a closer correlation between chromosome number and stomata counts than between chromosome number and stomata length, and the counts are made more easily than the measurements.

Some preliminary examinations were made from species or races of known chromosome number (Table II). The stomata frequency of the diploid *Secale* was nearly twice that of the tetraploid. Among the plants in the Arboretum, *Staphylea* was chosen because it was known to have diploid, tetraploid, and hexaploid species. The stomata counts are roughly proportional to the chromosome numbers. A similar correlation was found in the diploid and tetraploid species of *Deutzia* and in the tetraploid and hexaploid species of the *Caprifolium* section of *Lonicera*.

These preliminary comparisons of stomata counts in diploids and polyploids indicated that stomata counts might be used to determine the presence of polyploid races in certain species, and of polyploid species in certain genera. In talking over the possibilities of this work with Dr. Edgar Anderson, we learned that he had been making stomata counts from herbarium material at the Missouri Botanical Garden, and that Dr. G. L. Stebbins had used this method at the University of California. Dr. Stebbins informs us that, in his material, the size of stomata

is a better index of chromosome number than stomata frequency. We have tried the method with a number of genera in the herbarium, and it seems to have possibilities.

TABLE II
STOMATA COUNTS FROM FRESH LEAVES

Genus	Species	Chro. No.	Stomata per sq. mm. Lower epidermis
<i>Tradescantia</i>	<i>canaliculata</i>	2n	39
"	"	4n	19
<i>Secale</i>	<i>cereale</i>	2n	34
"	"	4n	19
<i>Staphylea</i>	<i>Bumalda</i>	2n	300
"	<i>colchica</i>	?	290
"	<i>pinnata</i>	4n	157
"	<i>trifolia</i>	6n	121
<i>Deutzia</i>	<i>gracilis</i>	2n	382
"	<i>reflexa</i>	4n	168
"	<i>scabra</i>	5n	100
<i>Lonicera</i>	<i>alseuosmoides</i>	4n	350
"	<i>Henryi</i>	6n	271

The number of stomata per unit of leaf surface seems to be reasonably uniform in many species, provided the counts are made from leaves of similar size and stage of maturity, and the samples taken from corresponding areas in different leaves. Long and Clements (1934) have shown that the number of stomata varies with the position on the leaf and the environmental conditions under which the leaf was developed. Accordingly, we have selected leaves only from fruiting specimens and taken the collodion peels from an area near the center of each leaf.

A modification of the collodion peel method used by Long and Clements was adopted for this work. We have used a solution of parlodion (5 per cent) in butyl acetate plus 5 per cent of butyl alcohol, as suggested by W. C. Darrah. A small drop of the solution is dropped on the lower epidermis of the leaf. If the leaf is pubescent, the pubescence may be removed by a preliminary peel, or it can often be removed with an eraser or piece of art gum. Drying of the solution is facilitated by the use of an electric hair dryer. When the edges of the parlodion begin to dry and separate from the leaf, the peel is removed

and cemented on a glass slide. The necessary data are written on the slide with a wax pencil. The stomata counts were made at a magnification of $\times 300$ or $\times 450$. The count for each specimen is based on an average of five records from various parts of the peel. The counts were later converted into number per square mm. of leaf surface.

The first genus selected for a study of stomata frequency in relation to polyploidy was *Malus*, a genus known to have both diploid and tetraploid species. The data obtained are shown in Table III.

TABLE III
MALUS SPECIES — STOMATA COUNTS

	Reported chr. no.	Number of specimens	Stomata per sq. mm.	
AMERICAN SPECIES				
angustifolia	4n	9	320-410 (7)	190-230 (2)
coronaria	4n	7	340-340 (2)	150-220 (5)
fusca		9	310-330 (2)	140-180 (7)
glaucescens	4n	7	310-340 (4)	180-220 (3)
ioensis	2n	6	300-390 (6)	
platycarpa		3		190-200 (3)
ASIATIC SPECIES				
baccata	2n	10	330-380 (3)	160-200 (7)
floribunda	2n	2	300-350 (2)	
Halliana		2	310 (1)	210 (1)
prunifolia	2n	3	320-430 (3)	
Sieboldii		3	320-420 (3)	
× Zumi	2n	2	330-340 (2)	

Most of the stomata counts fall into two general classes: those between 300 and 430 and those between 140 and 230. Presumably the higher counts indicate a diploid chromosome number, the lower counts a tetraploid chromosome number. Intermediate counts were found in six specimens — including *M. coronaria* and *M. Halliana* — and in the parthenogenetic triploid species *M. hupehensis*. If the stomata counts are a reliable index of polyploidy, it appears that both diploid and tetraploid races occur in *M. angustifolia*, *M. coronaria*, *M. fusca*, *M. glaucescens*, *M. baccata*, and *M. Halliana*. The tetraploid forms appear to occur more frequently in North America. There is no relation

between polyploidy and geographic distribution within a species, with the possible exception of *M. fusca*. This species extends from Alaska to California. The two apparently diploid forms were collected in Alaska and British Columbia, while only "tetraploid" forms were found in Washington, Oregon, and California.

In the closely related genus *Pyrus* only diploid species have been reported. Stomata counts from sixteen specimens, including six species, were rather variable, ranging from 120 to 320; but the average count was 190 per square millimeter.

The stomata counts of *Staphylea* species were obtained from herbarium specimens for a comparison with the counts obtained from the living plants. The average stomata frequency was 360 for the diploid, *S. bumalda*; 190 for the tetraploid, *S. pinnata*; and 220 for the hexaploid species, *S. trifolia*. While these counts are not entirely in accord with those from fresh specimens, the stomata counts in the diploid are much higher than those of the polyploids in both series of observations.

A study of stomata frequency in *Vaccinium* species indicates that both diploid and tetraploid forms occur in *V. canadense* and in *V. vacillans*. The stomata counts in the diploid and tetraploid forms are about 500 and 350, respectively. All four specimens of *V. corymbosum* examined had stomata counts ranging between 340 and 390, indicating that all were tetraploids as listed by Longley (1927). According to the stomata counts, the four specimens of *V. pennsylvanicum* examined are also tetraploids. *Vaccinium virgatum*, a hexaploid, according to Longley, had a stomata count of 290 in the one specimen examined.

The relation between polyploidy and geographic distribution suggests that many geographic races may be polyploid forms of the diploid species. We have started a series of investigations on polyploidy in relation to geographic distribution. Dr. Fernald has been very cooperative in this work, and has given us many suggestions regarding geographic races which are well represented in the Gray Herbarium.

The first species selected for study by means of stomata counts was *Gaylussacia dumosa* and its variety *Bigeloviana*. The species is found from Florida to Pennsylvania, while the variety extends from New Jersey to Nova Scotia. The stomata counts of the species ranged from 220 to 290 in seven specimens, with an average of 260; while in the variety, the stomata counts ranged from 220 to 360 in ten specimens, with an average count of 270. Apparently *G. dumosa* and its variety *Bigeloviana* have the same chromosome number; and in this case polyploidy is not involved in the taxonomic and geographic differences.

CONCLUSIONS

A comparison of diploid and tetraploid races of *Tradescantia canaliculata* shows a high degree of correlation between chromosome number and size of pollen mother cells, microspores, stomata, chloroplasts, and stomata frequency. The tetraploid has about half as many cells as the diploid forms, and a corresponding difference must exist in the rate of cell division. The number of major spirals in the meiotic chromosomes is greater in the diploid. Cytoplasmic streaming in the stamen hairs seems to be more rapid in the diploid. The tetraploid roots much better from stem cuttings.

Stomata frequency was used as an index of polyploidy in several genera. A positive correlation is found in diploid and tetraploid races of *Tradescantia* and *Secale* and in species of *Staphylea*, *Deutzia*, and *Lonicera*. Counts from herbarium material show some correlation between stomata frequency per square millimeter of leaf surface and known chromosome numbers of the species. If the stomata counts are a reliable index of chromosome numbers, it appears that both diploid and tetraploid races exist in certain species of *Malus* and *Vaccinium*.

DESCRIPTION OF PLATE 205

Camera lucida sketches of cells from diploid and tetraploid forms of *Tradescantia canaliculata*, and stomata size and frequency in two herbarium specimens of *Malus baccata*.

TRADESCANTIA

- Figs. 1 and 2. Anaphase of first meiotic division of diploid and tetraploid. $\times 800$.
 Figs. 3 and 4. Outlines of microspores and late prophase in diploid and tetraploid. $\times 800$.
 Figs. 5 and 6. Stomata from diploid and tetraploid races. $\times 250$.
 Figs. 7 and 8. Crystals from cells of stem in diploid and tetraploid respectively. $\times 400$.

MALUS

Stomata distribution from collodion peel.

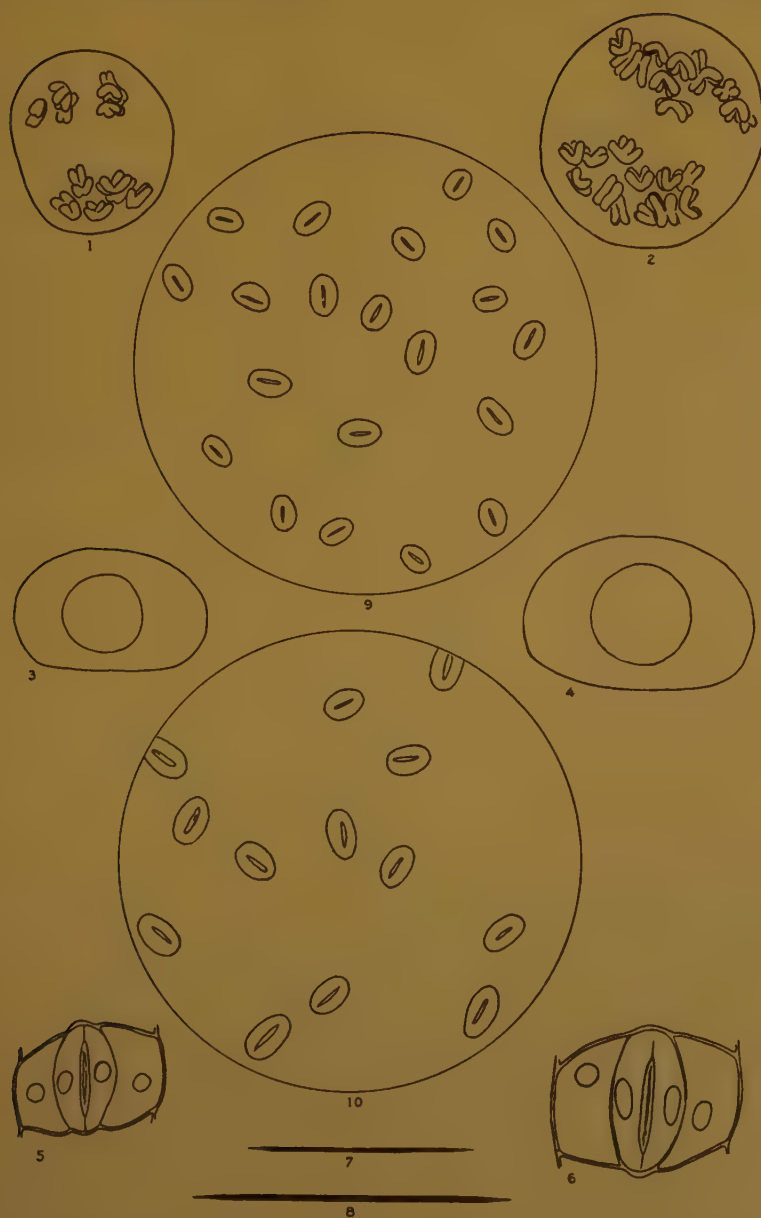
- Fig. 9. *Malus baccata*. Collected in Manchuria by Dorsett, no. 3609. Presumably a diploid form.
 Fig. 10. *Malus baccata*. Collected in Siberia by Sargent in 1903. Presumably a tetraploid form.

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STOMATA SIZE AND DISTRIBUTION IN DIPLOID AND POLYPLOID PLANTS.

ON THE TECHNIQUE OF INSERTING PUBLISHED DATA IN THE HERBARIUM

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BEGINNING with volume eighteen, number one, January, 1937, a small special edition of the *Journal of the Arnold Arboretum* has been prepared printed on one side of the paper only. The objective is to provide a form, without sacrificing two complete copies of each issue, for the preparation of "herbarium clippings" whereby pertinent taxonomic data may become available for insertion into herbaria in association with the actual specimens representing the species described or discussed. This special edition is available only on an exchange basis for similar material that may be used for preparing herbarium clippings for use at the Arnold Arboretum.

Those familiar with the older herbaria realize that individual botanists in the past have occasionally attached copies of their original descriptions to the herbarium sheets, but nowhere does one find any considerable number of these. In my own experience in the Philippines previous to 1923 I occasionally had typed and inserted into the herbarium copies of original descriptions, but like most busy botanists elsewhere I never found time to clip and insert copies of my own published descriptions. It was only after my transfer to the University of California in 1923 that it occurred to me that a more comprehensive plan of inserting actual descriptions into the herbarium would be advantageous. Thus over a period of nearly six years many thousands of such items were incorporated in the herbarium, the great advantage being that even where authentically named specimens were not available, the actual description was in place. Special attention was given to published data on the floras of China, the Philippines, and Malaysia. This trial, involving perhaps 40,000 entries, convinced me of the great utility and the eminent practicability of the scheme, although while engaged on this task I was seriously assured by some of my colleagues that the project was an impracticable one.

On my transfer to the New York Botanical Garden in 1930, I there initiated the same system on a small scale in the early part of the year, but I always had the feeling that some of my associates there considered the matter of slight value and perhaps some of them even thought that

I was to a slight degree mentally unbalanced in initiating what was a most radical innovation. In November, 1930, when unexpectedly it became possible to secure the services of numerous individuals through the privately supported Emergency Work Bureau, it became immediately necessary to plan productive projects whereby the talents of this supplementary force could be utilized to advantage. Starting with six temporary employees, the number was rapidly increased until within two months about 100 extra employees were at work. The further development of the preparation of published data for herbarium inserts was made an important project. A certain number of assistants, under supervision, were assigned to the task of preparing the clippings, utilizing two printed copies of the volume or article that it was desirable to clip. Others were assigned to the task of typing original descriptions and critical notes from the older periodical literature. Because of lack of interest on the part of certain staff members, not accustomed to the advantages of the system, the geographic areas first stressed were the same as those selected at the University of California. Later this was extended to cover all fields in which the New York Botanical Garden was actively interested, North, Central, and South America, the West Indies, Asia, Malaysia, and Polynesia.

No record of the number of items incorporated in the herbarium was kept. A very conservative estimate is that the number is now over 700,000 and it may well be greatly in excess of that number. Some idea of the extent of the operations may be gained by the statement that among the periodicals from which practically all pertinent taxonomic data have been excerpted, either by clipping or by typing, are complete sets of the following:

Bulletin de l'herbier Boissier; Journal of Botany, British and Foreign; Kew Bulletin of Miscellaneous Information; Notes from the Royal Botanic Garden, Edinburgh; Notizblatt des Botanischen Gartens und Museums, Berlin; Linnaea; Philippine Journal of Science; Sunyatsenia; Sinensia; Lingnan Science Journal; publications of the Fan Memorial Institute of Biology, Metropolitan Museum (Academia Sinica), Science Society of China, and the Peking Natural History Society; Bulletin de la Société botanique de France, Notulae Systematicae (Paris), Notulae Systematicae (Leningrad), Bishop Museum publications in botany; Field Museum publications in botany; nearly all of the official publications of the botanical garden, Buitenzorg; all of the official publications of the New York Botanical Garden, including the North American Flora; Records of the Botanical Survey of India; Annals of the Missouri Botanical Garden; Contributions from the Gray Herbarium; Contribu-

tions from the United States National Herbarium; Journal of the Arnold Arboretum; the Hookerian series of botanical periodicals preceding the establishment of the Journal of Botany, British and Foreign; Hooker's *Icones Plantarum* (the first ten volumes reproduced by photostat); Proceedings of the Biological Society of Washington; Mededeelingen van's Rijks Herbarium, Leiden; Bulletin mensuel de la Société Linnéenne de Paris; Bulletin du Muséum d'histoire naturelle (Paris); Bulletin de l'Académie internationale de géographie botanique; *Acta Horti Gothoburgensis*; *Candollea*; *Annuaire du Conservatoire et du Jardin botaniques de Genève*; *Gentes herbarum*; Transactions of the Linnean Society, University of California Publications, Botany, and others.

Much of the systematic data have also been excerpted from another long series of periodicals, including the *Botanische Jahrbücher*, Fedde's *Repertorium* and its *Beihefte*, *Beihefte zum Botanischen Centralblatt*, *Annales des sciences naturelles*, *Le monde des plantes*, *Botanical Gazette*, *Bulletin of the Torrey Botanical Club*, *Rhodora*, *Acta Horti Petropolitani*, *Gardeners' Chronicle*, *Botanische Zeitung*, *Bonplandia*, *Hedwigia*, *Journal de botanique* (Morot), *Flora*, *Journal of the Washington Academy of Science*, *Bulletin de la Société impériale des naturalistes de Moscou*, *Mededeelingen van het Botanisch Museum en Herbarium van de Rijks Universiteit de Utrecht*, and scattered articles in a large number of other periodicals.

Supplementing these data, many thousands of clippings were prepared from miscellaneous reprints from a wide variety of sources, various modern and even some older monographs, independently published volumes, the numerous original descriptions in Kuntze's *Revisio generum plantarum*, and from such extensive works as those of Maximowicz on the floras of Japan and Manchuria, and the more recent ones of Handel-Mazzetti on the flora of China, *Plantae Wilsonianae* and similar works. The work is still being continued, now supported by federal and state relief funds.

The hundreds of thousands of items from sources indicated above, some the original printed data, some typed copies, some reproduced by the photostat method, are actually incorporated in the herbarium of the New York Botanical Garden, thus making this great reference collection a most outstanding one in which resident and visiting investigators can prosecute intensive work without the great loss of time entailed in other institutions where a very high percentage of one's time must of necessity be devoted to library search. Under this system, the library to a remarkable degree has been made an actual part of the herbarium, with

original descriptions, critical notes, illustrations, redescriptions, extensions of ranges, etc., actually associated with the reference specimens. Here in many groups, and for almost entire floras in some cases, the systematist finds before him practically everything that he needs, in the way of the printed record, without the necessity of having, in each case, to spend hours, or days, or even weeks, searching for the needed references in the tremendously scattered source literature that he may need to consult in connection with the problem under investigation. In other words, within limits, the herbarium is not only an herbarium in the generally accepted sense, but it is an herbarium, a card catalogue and a library, all combined in one working unit.

Since this large scale work was undertaken, first at the University of California in 1923, later at the New York Botanical Garden in 1930, and more recently at the Arnold Arboretum, modifications or adaptations of the same idea have been adopted at the United States National Herbarium, the Philadelphia Academy of Natural Sciences, and at several institutions in China. To make currently published data available for this purpose special editions of certain periodicals are now being issued, printed on one side of the paper only, such as "Sunyatsenia," the Berlin "Notizblatt" and Fedde's "Repertorium"; to this short list is now added the "Journal of the Arnold Arboretum." In the past at least some parts of "Das Pflanzenreich" have been so printed in limited editions.

There is little agreement as to how such data should be incorporated into the herbarium. When I first commenced inserting occasional descriptions into the herbarium many years ago, they were automatically treated like herbarium specimens, and mounted on standard herbarium sheets. Occasionally they were pasted on the sheet bearing the type specimen. These are apparently the first methods that one thinks of. Both have certain obvious and serious disadvantages. I then developed the idea of pasting the description inside of the specimen cover so that in studying the included botanical material, one would have both the description and the specimen or specimens before him. Soon this scheme was found to be faulty and it was quickly abandoned for the one adopted at California, New York, and the Arnold Arboretum, i.e., to paste the description or the clipping rather lightly by its corners on the outside of the specimen cover, on the lower left hand corner of the folded sheet.

A serious objection to mounting single descriptions in the middle of a standard herbarium sheet, aside from the relatively high cost of mounting paper, is that such a sheet may become misplaced among the mounted specimens. In any case, if the first sheet of a series bears

merely a printed or typed description it effectively obscures the actual specimens, a point that needs consideration when one is making hurried comparisons. If the slips are firmly pasted, as unfortunately they are in most cases, they cannot be easily removed. Again, if they are placed in the middle of a standard sheet, as is usually the case, there is inadequate space for adding other descriptions, such as those of species reduced to synonymy, redescriptions, and later critical notes; for such data as well as for original descriptions of species reduced to synonymy, one is forced to use an extra sheet for each. One could cite cases, where with one description to a sheet it might conceivably be necessary to prepare and insert not one or two or three sheets, but literally scores of them, for many "recognized" species are burdened with scores of synonyms. This system, consistently followed, adds a tremendous amount of needless paper to the herbarium and results in a very great waste of expensive herbarium storage space. The chief objection to pasting an original description on the type sheet itself is that frequently adequate space is not available unless a part of the specimen itself be obscured by the clippings.

The reason I soon abandoned pasting the descriptions on the inside of the cover was because hurried or careless herbarium workers tended to discard frayed, torn, or stained covers without glancing inside to see whether or not there were contained data in the form of clippings or typed descriptions. Specimen covers that contain no data other than a description pasted on the inside are particularly apt to be discarded, for without glancing inside, one cannot determine whether or not there are included clippings.

Having stated some of the serious objections to the first two methods, it is well to indicate the advantages of the third method with which I have now had over twelve years' experience; and not one based on a limited, or even a local use of the system, but rather with a world viewpoint, involving hundreds of thousands of items. As indicated above, one of the consistent criticisms of any method of making these herbarium inserts has been that it "adds too much paper" to the herbarium. With the herbarium sheet method I agree fully with this criticism. With the specimen cover system, utilizing a rather thin, tough, durable paper, such as Nibroc Duracel 40 lbs., and adding from one to many clippings to a single sheet, no just criticism can be made, for the space taken does not equal that needed for a single average mounted botanical specimen. The system, however, does involve the acceptance of the specimen cover plan, i.e., all sheets of a single species to be included in a single thin cover within the stiffer genus cover; few to many specimen covers

with their included sheets may be inserted within a single genus cover. If this be adding too much paper, then the specimen cover system is condemned at the outset by individuals, perhaps, who have never used it. The specimen covers serve another purpose in that they very greatly protect mounted specimens from undue breakage.

In practice a high percentage of the sheets will have but a single description, this the original one. For common, widely distributed, and variable species, and especially those that have a complicated synonymy, the sheets will eventually bear from two or three to very numerous items. The first item should be placed about a half inch above the lower margin in the left hand corner of the folded sheet, lightly gummed by the corners only. Additional items are added in sequence of their preparation above the first one. To the same sheet should be attached original descriptions of species that have been reduced, if such occur, as is frequently the case. To the sheet should also be attached re-descriptions, critical considerations by later authors, and especially those items that contain literature references, synonymy, and important extensions of range; in fact, all pertinent data of importance that may have been published by various authors that appertain to the species under consideration. In extreme cases a sheet may be so thoroughly covered by supplementary published data of one type or another that all available space is taken. In this case a single sheet of the same stock as the specimen cover may be utilized for the overflow, this to be inserted inside the first cover. As incorporated material relating to supposedly distinct species is found to appertain to a single species, the two covers may be "telescoped" one within the other, or the data may be removed from one sheet and attached to the other.

This brings up a most important point for those who use either the herbarium sheet method, or the species cover system. The clippings should not be pasted firmly to the carrying medium under any circumstances, but rather they should be pasted lightly by their corners so that, as necessary, they may readily be removed for transfer to other positions. Only narrow strips, that might be easily torn if pasted only by their ends, should receive more adhesive. This is a most important point and any curator adopting this clipping system or any modification of it, should give careful consideration to the simple problem of attaching the slips before a system has been adopted that may eventually be found to be very disadvantageous. Whether typed data be attached to standard herbarium sheets or to specimen covers, they should be prepared on thin paper of good quality, such as onion skin paper rather than on the heavier standard paper, this to save space in the storage

cases, for when one contemplates the addition of tens of thousands of typed entries into the herbarium, the problem of space becomes distinctly important.

The general and preferred method of preparing clippings is to take two copies of the work to be clipped, arrange the sheets as page proof, and to each entry add in the text or at the margin, an abbreviated but clear reference to the author, periodical or title, volume, page and date; these to be either typed, written long hand, or stamped. For standard periodical references the citations may be greatly abbreviated, such as JOB. instead of Journ. Bot.; BG. instead of Bot. Gaz.; BJ. instead of Bot. Jahrb.; KB. instead of Kew Bull.; BTBC. instead of Bull. Torr. Bot. Club; and JLSB. instead of Journ. Linn. Soc. Bot. When only one copy of a paper desirable for clipping is available, every other page must be typed, photographed or photostated, the citations to be added as part of the typing task. For older periodicals, rare items, and important articles where reprints are unavailable, all entries should be typed. In some cases entire volumes may be reproduced by the photostat method and these sheets then clipped. Obviously the original printed data or a photographic reproduction of it, is preferable to a typed copy.

When a sufficient number of clippings or typed slips are available, they are systematized by families and genera, and then inserted into the herbarium in their proper places. Normally the best procedure to follow is for some botanist familiar with the flora, or the group, to examine the entries and indicate obvious reductions to synonymy, thus avoiding the undue scattering of items appertaining to a single species under different names in the herbarium.

In special cases, such as the preparation of a monographic work or a revision of a special group, all original descriptions and critical notes for every species may be prepared. This, however, involves a very great amount of bibliographic work, other than straight routine, and generally involves a considerable amount of supervisory time by staff members, the ordinary routine employee not being equipped to find the references needed. On the whole this method of compiling data is wasteful in the extreme, and is in general impracticable unless a trained botanist be willing and ready to devote a very large amount of time to the project.

Some curators who have recently adopted this plan restrict their herbarium insertions to copies of original descriptions. From my standpoint, and based on my own extensive experience, while this is better than nothing, yet a serious error is made in not including data where synonymy with literature references and citations of specimens are given. Not infrequently a later author's consideration of a species is

distinctly more illuminating than is the original description. It is particularly important that all pertinent additional data, redescrptions, critical notes, supplementary data on type specimens, and significant extensions of range be preserved and incorporated on the sheet or sheets with the original description. Except in those cases where new names appear in current literature, important published data may be entirely overlooked, for manifestly it is impossible for the average botanist to master and keep in mind the tens of thousands widely scattered and unindexed observations. References check against each other, and automatically in examining long series of assembled data regarding this or that species, one often detects errors, some perhaps relatively unimportant, but frequently most exasperating, particularly when they include incorrect volume numbers, page references, dates of publication, and occasionally even wrong periodical titles; many botanists apparently do not check their cited references on the originals, and an error once made in a standard work may automatically be repeated over and over again. When discrepancies are noted in a series of published references, it is a simple matter to determine which is correct by consulting the original publication. As a side issue to this work scores of binomials overlooked by the compilers of *Index Kewensis* and its supplements were detected.

So much of the criticism of the principle of making herbarium inserts has come from individuals unfamiliar with its extensive recent development in a few institutions that I have become impervious to it. To early criticisms to the effect that the scheme was impracticable, I believe that it has been abundantly proved that the reverse is the case. To those who criticize without the basis of actual experience little attention need be given. To those who utilize the data and then criticize the system because not all the needed and published data have been incorporated, or because some non-technical assistant has filed a reference in the wrong place, the answer is obvious; cooperate in helping to complete the records. Those interested in the printed page may look on me as a vandal, because annually I clip many hundreds of pages of technical descriptions. If a library has a complete set of a periodical, I see little reason for considering that all reprints from that periodical are sacred and must be maintained on the shelves as separate items. I frankly believe that frequently the best place for the reprint is in the herbarium in association with the plants to which the data appertain rather than on the library shelf.

One great handicap is the attitude of the average herbarium worker. He has so much productive work to accomplish that he cannot afford

to take the time to prosecute the necessary routine in preparing and inserting herbarium clippings covering his own contributions much less those of numerous other botanists. He forgets that what is accomplished is of benefit not only to himself but to all who in the future may have occasion to utilize the herbarium reference facilities, and that what he accomplishes, no matter how little, is a contribution to the efficiency of his own future work as well as to the efficiency of others.

When one is dealing with the problems of identification of collections coming from little known parts of the world, particularly from areas not covered by published floras or even systematic lists, one must of necessity spend a disproportionate part of his time locating the widely scattered published descriptions and critical notes, which he must, or at least should, consult and compare critically with his material. To find these data assembled and arranged in advance, and actually in the herbarium, whether specimens representing the named species are available or not, adds tremendously to one's efficiency and should tend to more accurate, complete, and dependable work.

After over twelve years' experience with this innovation in herbarium practice and particularly with the large scale demonstration as developed at the New York Botanical Garden I became more and more enthusiastic regarding its merits as the increasing number of references *in situ* in the herbarium demonstrate its extreme utility. I feel safe in asserting that no large herbarium can safely ignore the challenge and avoid the issue of incorporating in its working collections at least those current items published by its own staff members. I am convinced that this innovation is one of the most important advances made in herbarium technique in the last few decades. Objections invariably come from individuals long accustomed to standard, or better, static technique. They claim that the work cannot be done with their present resources; that of the specimens, the literature in the form of a library, and comprehensive indices are available, it is not necessary to take the time to incorporate such data in the herbarium; that the plan involves putting too much paper into the herbarium; that they have too much productive work to do to warrant taking the time to accomplish this routine task; and (never having done it) they believe that it is impracticable. These are some of the current but invalid objections.

Several years ago when I was directing the work of several typists engaged solely in copying original descriptions from the older literature, the curator of one of our large herbaria courteously but firmly declined to accept my offer to supply him gratis with a carbon copy of each description thus reproduced. He had access to extensive herbarium

facilities, to a great botanical library, and to comprehensive indices and card catalogues, and could see little to be gained by having the original descriptions incorporated in the herbarium. How many thousands of steps might have been saved within a single year, and how much time have been conserved in the endless consulting of hundreds or even thousands of descriptions in the library made no impression. In searching for objections to an obviously important innovation the average herbarium executive, handicapped by a long established and static routine, forgets that those who come after him will not have his intensive knowledge of a special flora, a special group, or of a special literature, but that each worker must, to a certain degree, forge his own tools. The work of all future investigators is made infinitely easier if the current worker would but incorporate, from time to time, in association with the specimens, at least his more important contributions. It is noteworthy how objections fade when a botanist accustomed to the old method of botanical specimens plus a card-catalogue or an index, plus a library, borrows all the material in a special group, specimens and covers with incorporated printed or typed data, from an institution in which the system has been well established, and finds to his surprise that his bibliography for this or that group is largely done for him; that he has before him most of the published descriptions he needs, whether represented by authentically named specimens or not; and not infrequently he finds references from obscure sources of which he had no previous knowledge.

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BIBLIOGRAPHICAL NOTES

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Edwards's Botanical Register. A brief note in "British and Irish Botanists" yields the following information: "Sydenham Teast Edwards a celebrated botanical artist was born at Abergavenny about 1769 and died in Chelsea in 1819. He illustrated R. W. Dickson's 'Dictionary of Practical Gardening,' 1805-07, 'Botanical Magazine,' 1786-1814, and 'Botanical Register,' 1815-19." In the *Gardeners' Chronicle*, 1898, xxiii, 340, Mr. W. Botting Hemsley gives a more extended account of Mr. Edwards, and believing this to form an interesting introduction to the study of the *Botanical Register* we quote in part:

"In 1828 Samuel Curtis then proprietor of the *Botanical Magazine*, wrote of Mr. William Curtis, its founder, as follows: 'But the artist of most use to Mr. Curtis was Sydenham Taste (sic) Edwards, who was introduced to him for the purpose of his patronage by a Mr. Denman, who being of a scientific turn of mind, and happening to be at Abergavenny, noticed Edwards whose father was a school master and the organist there. Young Edwards, whilst a boy, had copied some of the plates of the *Flora Londinensis*, which were shown to Mr. Curtis, who was so pleased with them that he sent for him to London, and had him instructed in drawing, in which he improved very rapidly, and soon became able to draw and etch the plates of the *Flora Londinensis* and the *Botanical Magazine*. The drawings for the *Magazine* were entirely his own for many years, and were executed with a correctness not before known in periodical publications. He attended Mr. Curtis on most of his excursions in search of natural history and became the companion rather than the servant of his patron.' After Mr. Curtis's death in 1799, Edwards continued sole artist for the *Botanical Magazine* until 1815, when, in conjunction with John Bellenden Ker, he founded the *Botanical Register*, on much the same lines as the *Botanical Magazine*, though he added floral analyses to some extent." Edwards and Ker were joined by Sansom the engraver and on the title-page of volume fifteen (1829) John Lindley's name is mentioned for the first time as editor.

The *Botanical Register* comprises thirty-three volumes, published in parts from 1815 to 1847, issued on the first of each month. There are eight plates to a part, often with a double plate counting as two.

The plates are dated and in volumes one to nineteen the first eight plates are dated Mar. 1 and the last eight Feb. 1 of the following year, the title-page of the volume giving only the year of the first plates. With vol. xx (1835) the practice is reversed and the date of the last plates given, until eventually the volumes comprise a complete year from Jan. to Dec. and the year on plates and title-page agree. In the absence of covers these discrepancies may easily be overlooked and the following citation of them be helpful.

Vol.	i (1815)	Mar.-Dec. 1815	(Pl. 1-76);	Jan.-Feb. 1816	(Pl. 77-90)
"	ii (1816)	" " 1816	(" 91-163);	" " 1817	(" 164-177)
"	iii (1817)	" " 1817	(" 178-248);	" " 1818	(" 249-263)
"	iv (1818)	" " 1818	(" 264-335);	" " 1819	(" 336-349)
"	v (1819)	" " 1819	(" 350-421);	" " 1820	(" 422-435)
"	vi (1820)	" " 1820	(" 436-506);	" " 1821	(" 507-520)
"	vii (1821)	" " 1821	(" 521-590);	" " 1822	(" 591-605)
"	viii (1822)	" " 1822	(" 606-675);	" " 1823	(" 676-689)
"	ix (1823)	" " 1823	(" 690-762);	" " 1824	(" 763-777)
"	x (1824)	" " 1824	(" 778-853);	" " 1825	(" 854-867)
"	xi (1825)	" " 1825	(" 868-940);	" " 1826	(" 941-955)
"	xii (1826)	" " 1826	(" 956-1029);	" " 1827	(" 1030-1043)
"	xiii (1827)	" " 1827	(" 1044-1116);	" " 1828	(" 1117-1130)
"	xiv (1828)	" " 1828	(" 1131-1202);	" " 1829	(" 1203-1216)
"	xv (1829)	" " 1829	(" 1217-1291);	" " 1830	(" 1292-1305)
"	xvi (1830)	" " 1830	(" 1306-1376);	" " 1831	(" 1377-1391)
"	xvii (1831)	" " 1831	(" 1392-1462);	" " 1832	(" 1463-1476)
"	xviii (1832)	" " 1832	(" 1477-1549);	" " 1833	(" 1550-1564)
"	xix (1833)	" " 1833	(" 1565-1637);	" " 1834	(" 1638-1652)
"	xx (1835)	" " 1834	(" 1653-1727);	" " 1835	(" 1728-1741)
"	xxi (1836)	" " 1835	(" 1742-1821);	Jan. 1836	(" 1822-1828)
"	xxii (1836)	Feb.-Dec. (Pl. 1829-1919)			
"	xxiii (1837)	Jan.-Dec. (" 1920-2014)			

In volumes xxiv (1838) to xxxiii (1847), like volume xxiii comprising an entire year from January to December, the plates of each volume are separately numbered. There are from 66 to 71 plates for each year.

An Appendix to the First Twenty-three Volumes, consisting of an index to the volume and nine additional undated colored plates, was published in 1839.

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